THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

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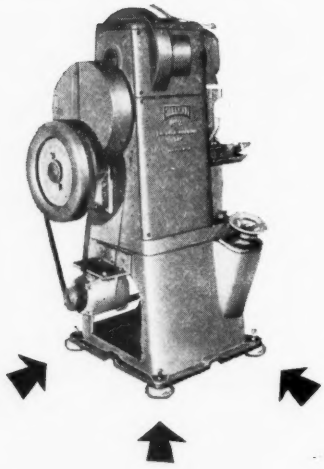

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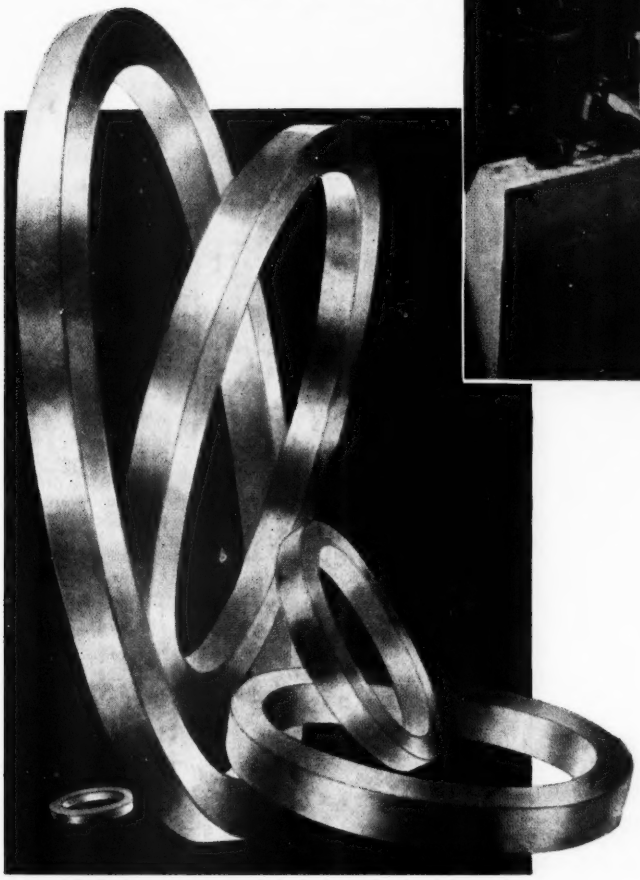

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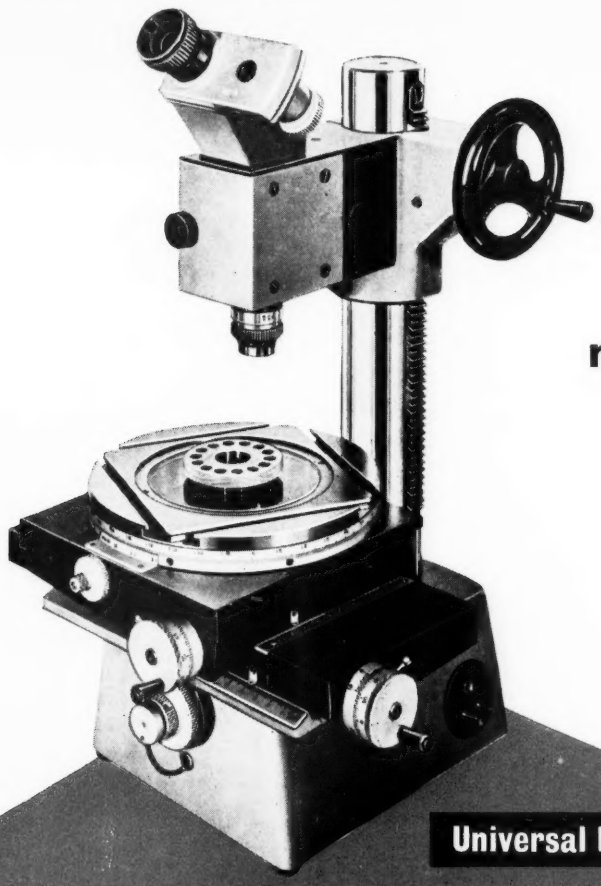

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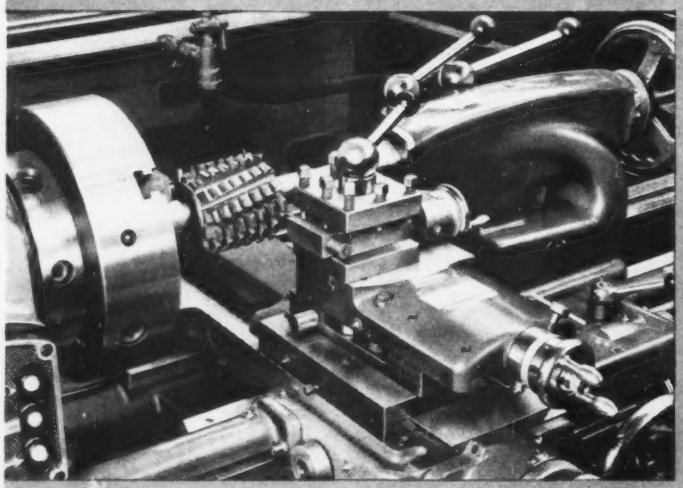

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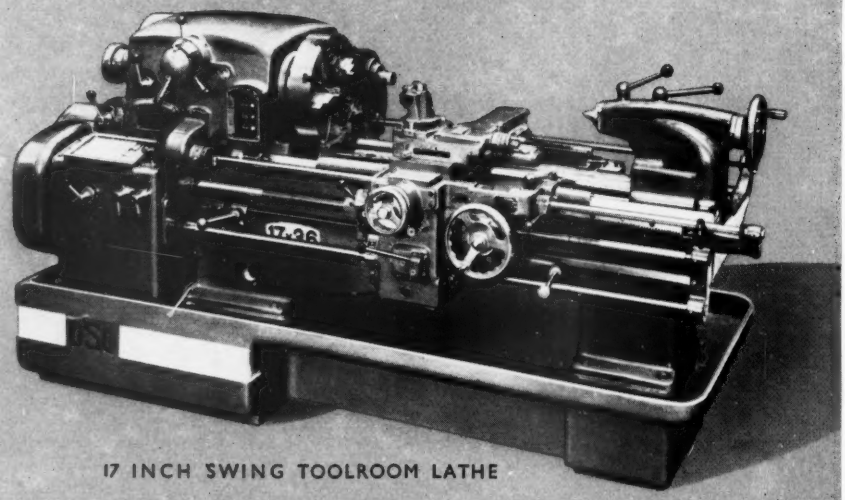

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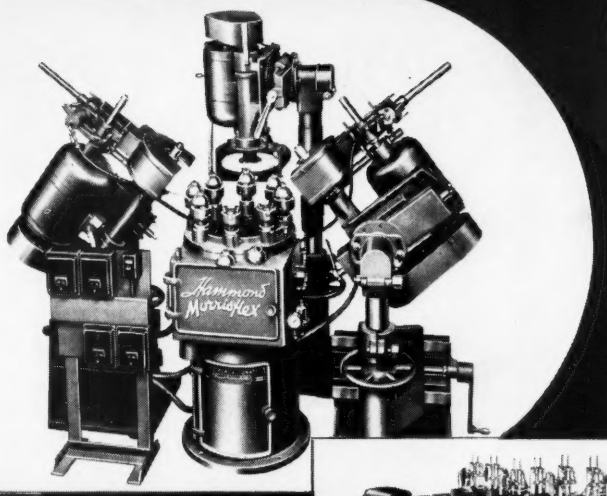

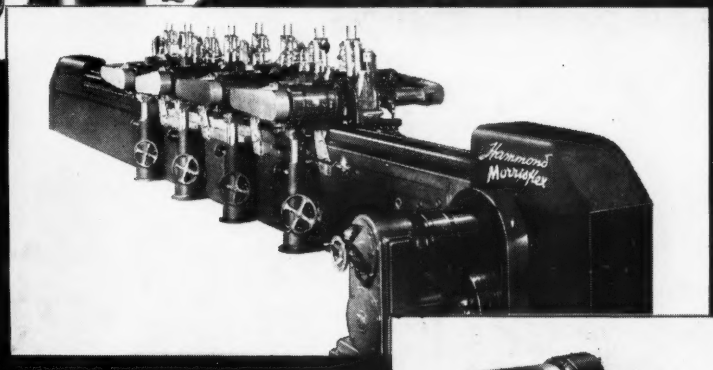

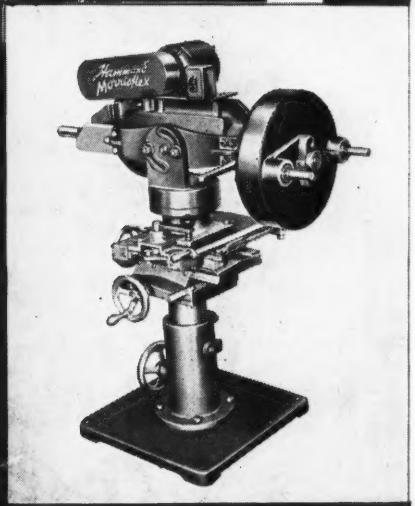

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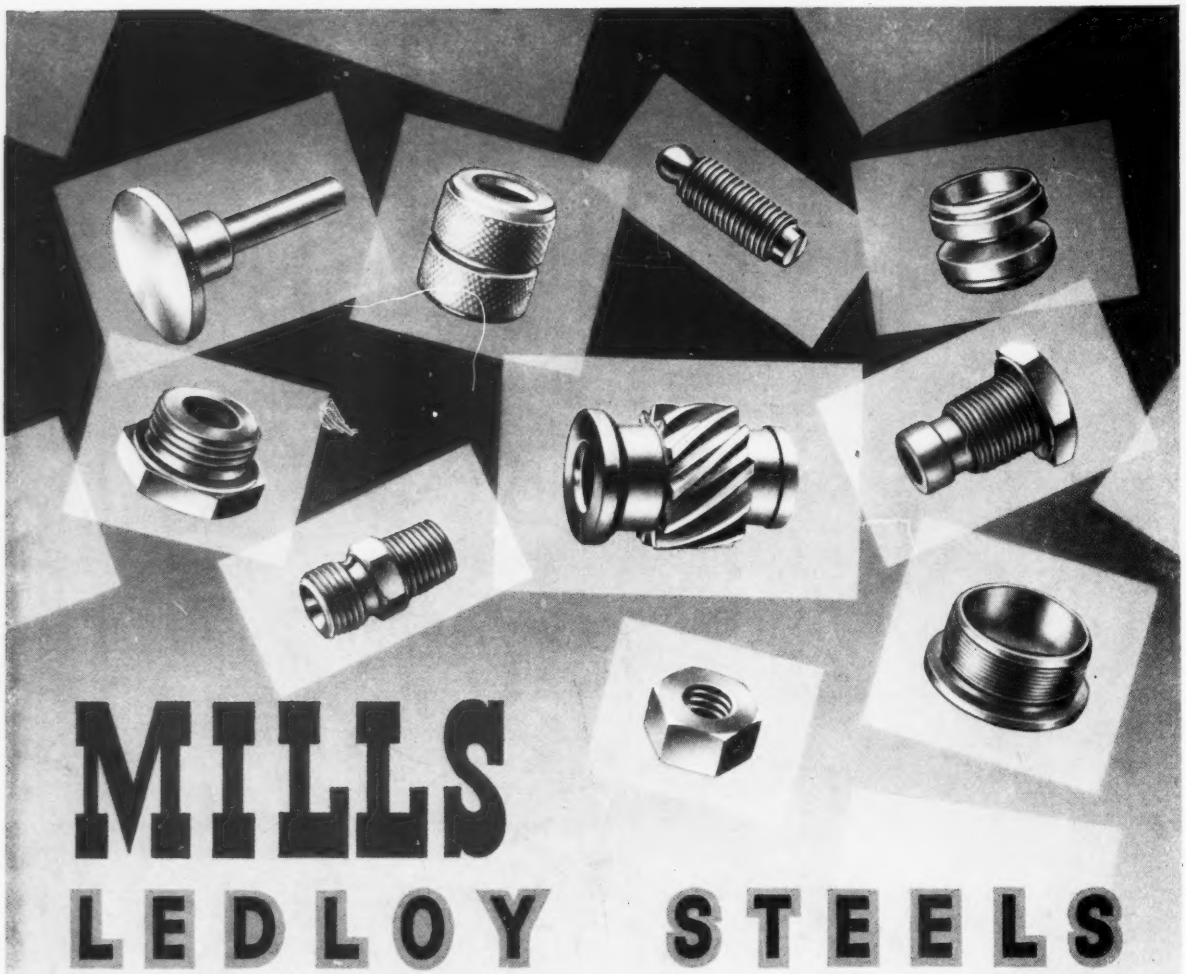

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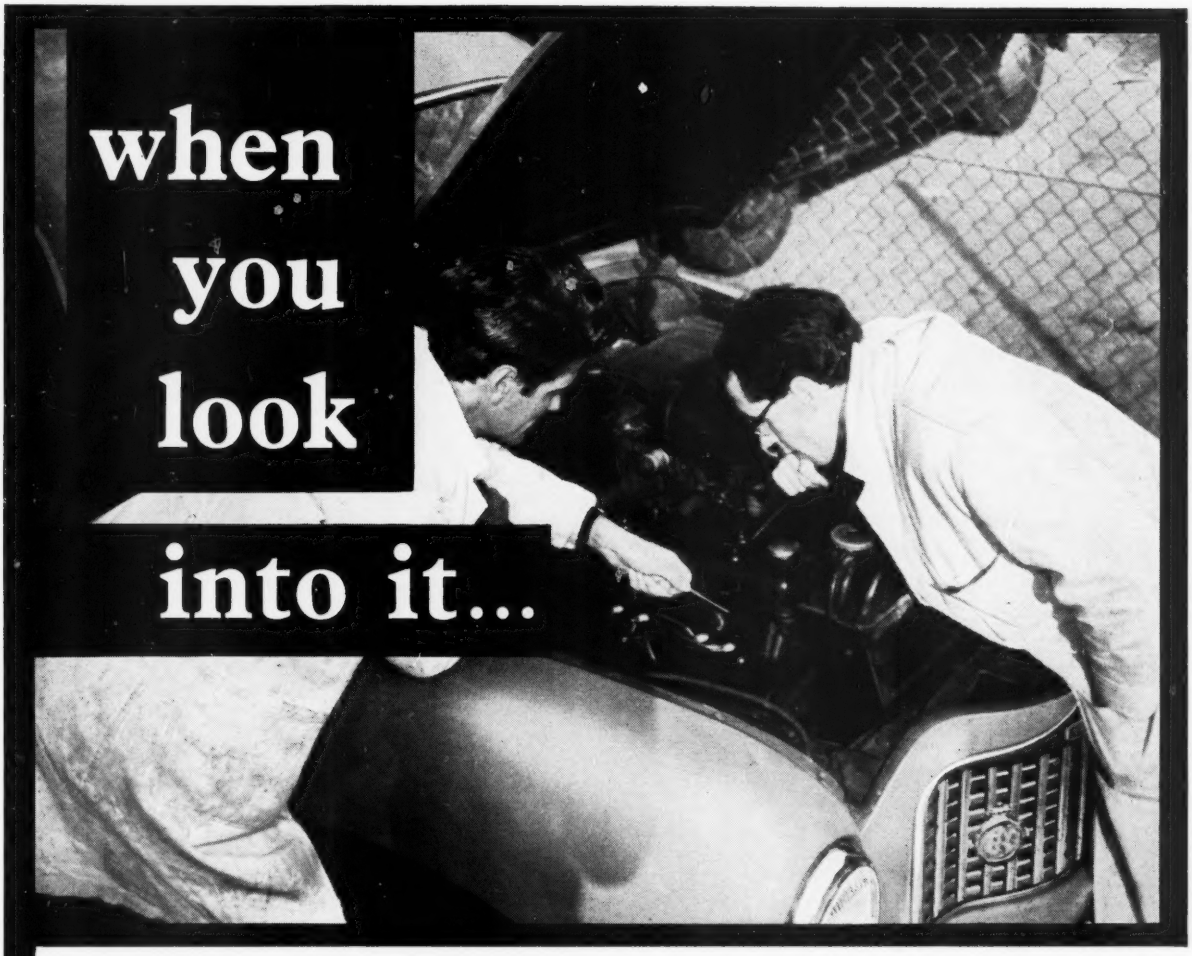

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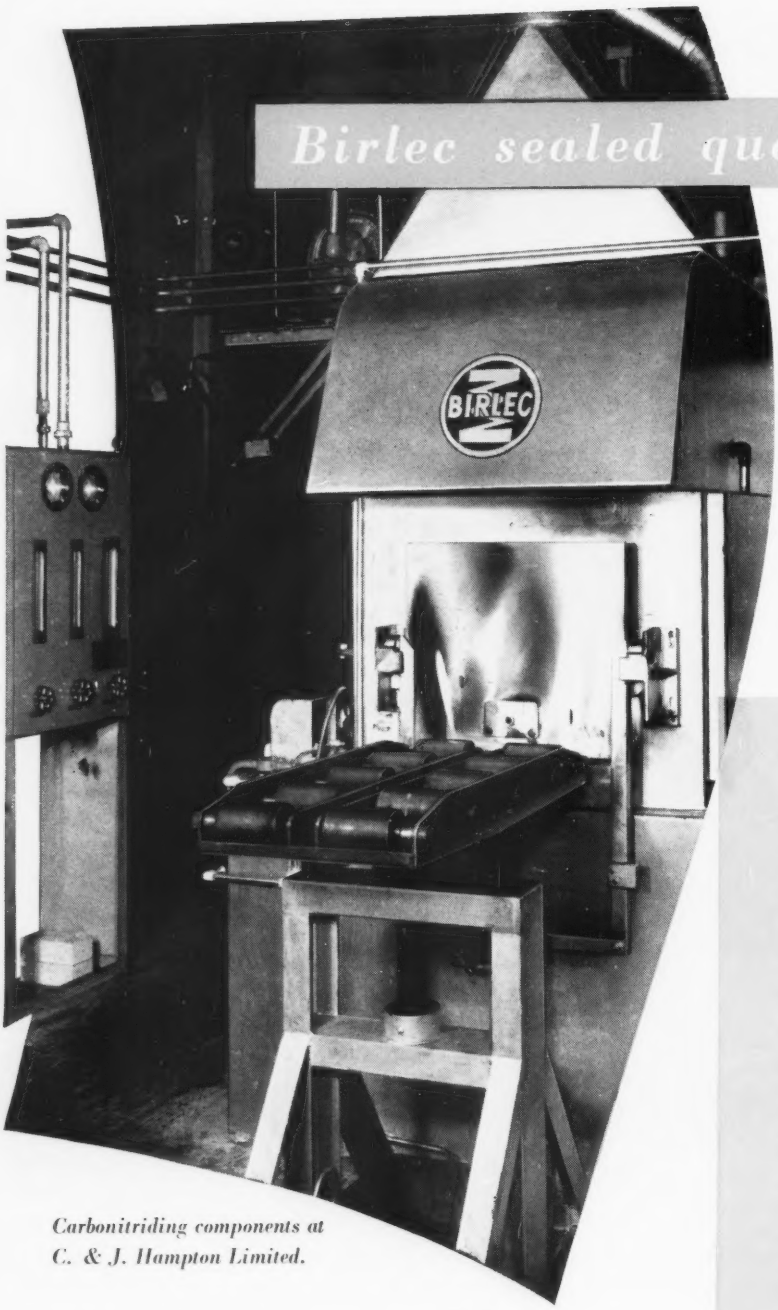

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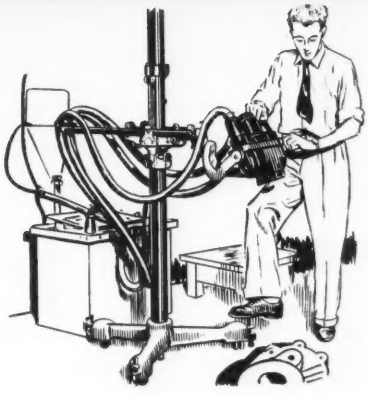

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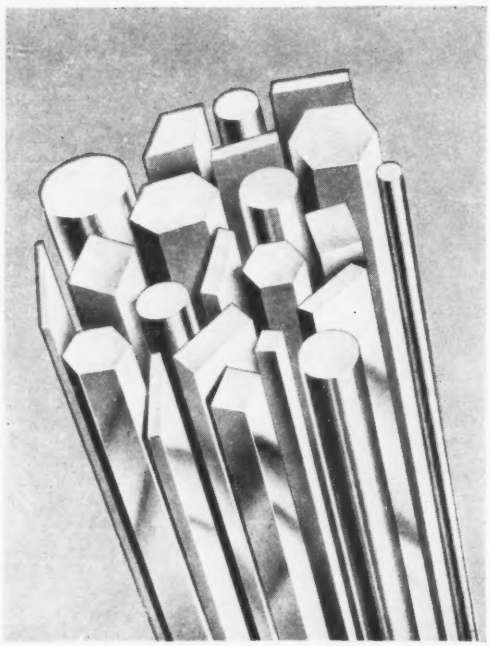

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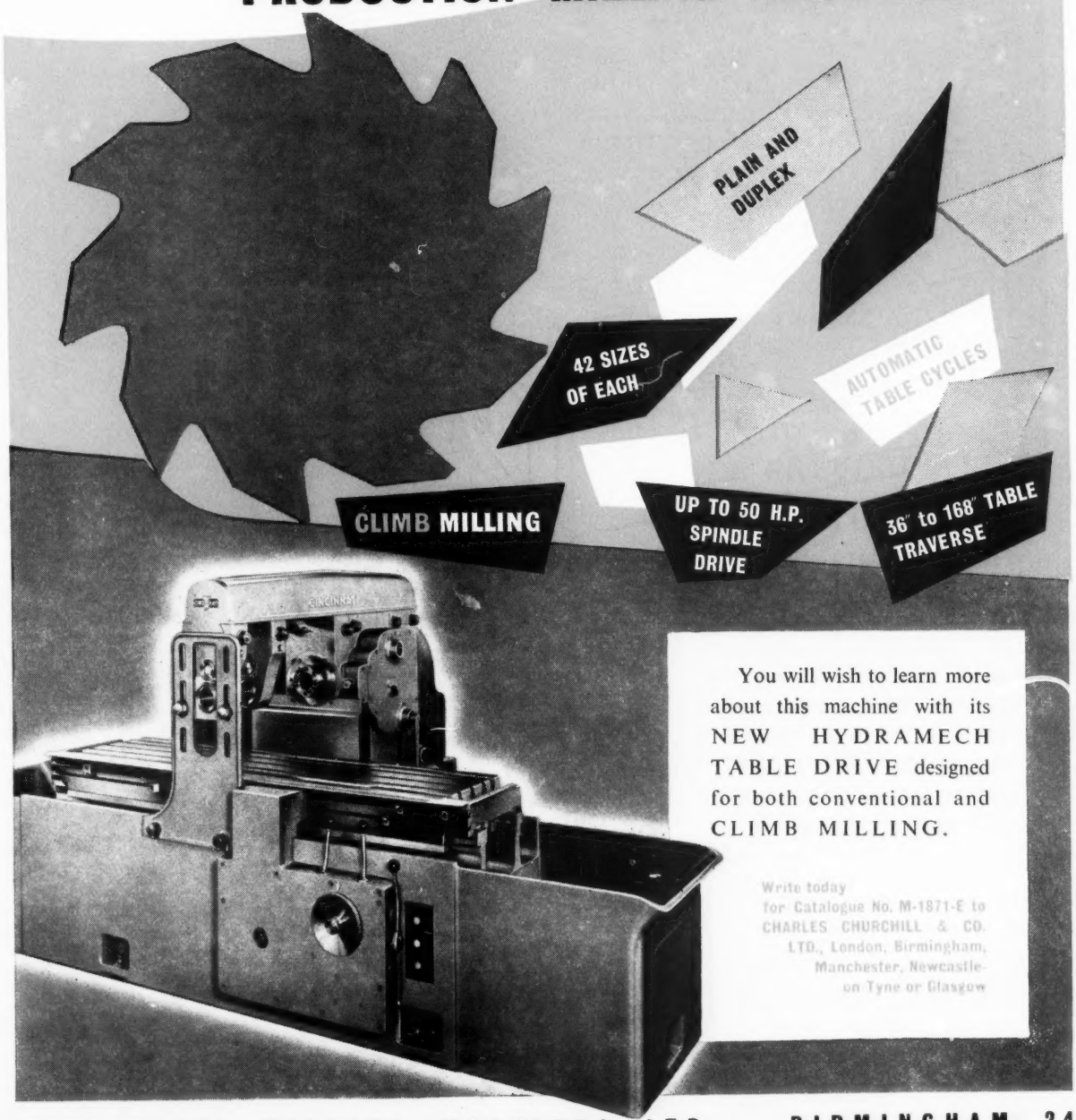

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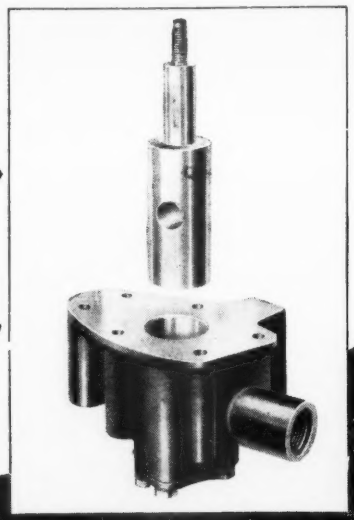

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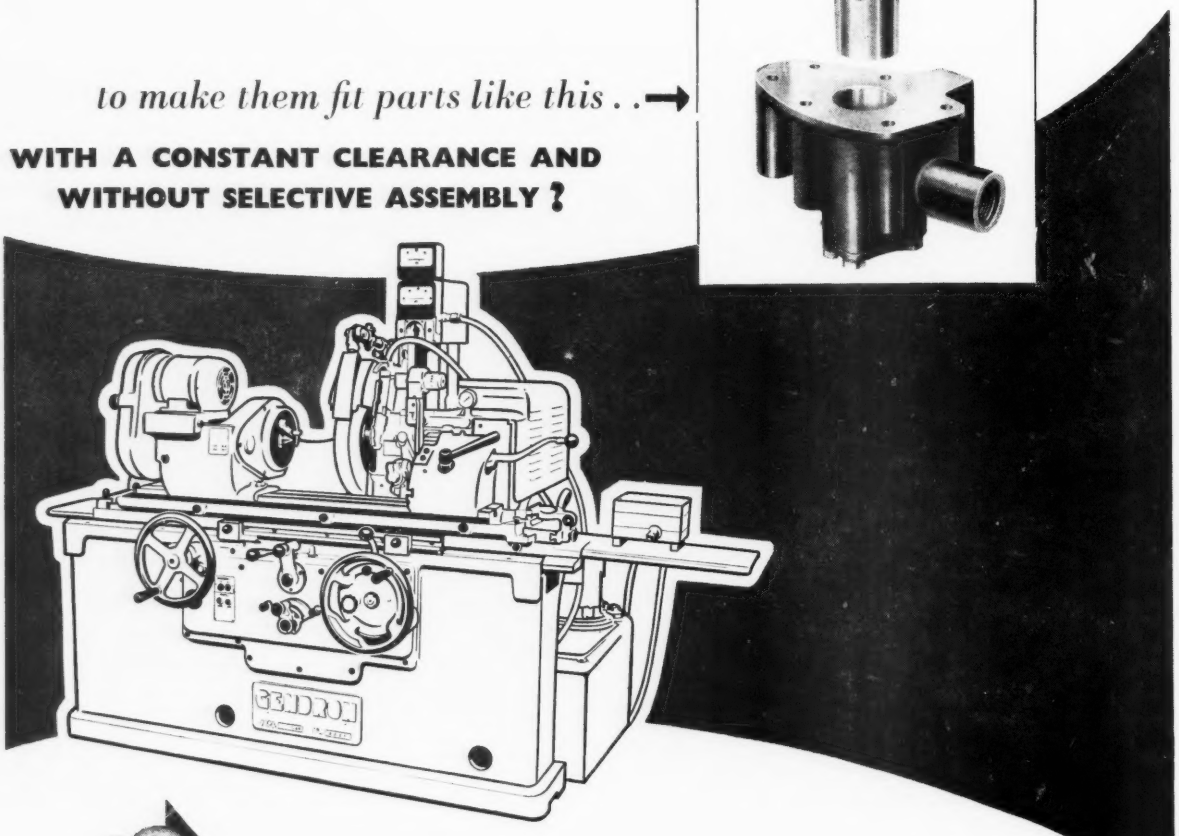

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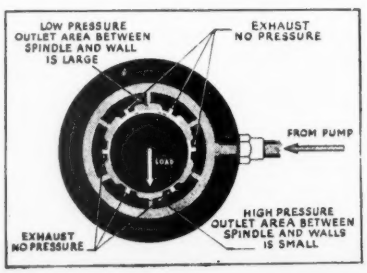
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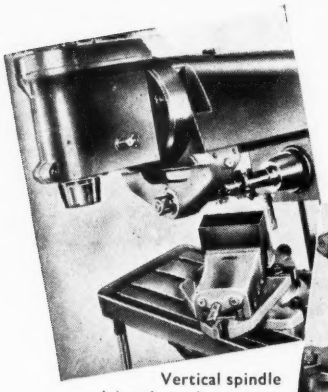
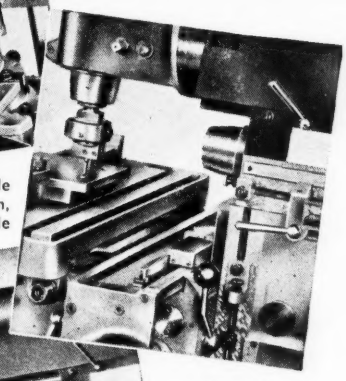


Vertical spindle drive through overarm, independent of horizontal spindle



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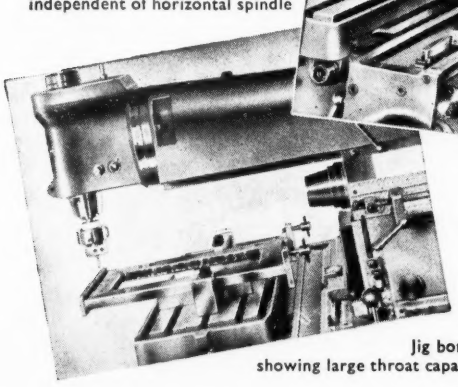

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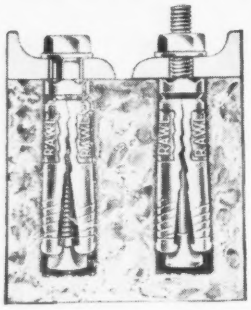

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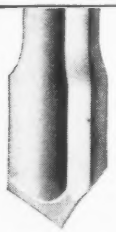

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STARDRILLS

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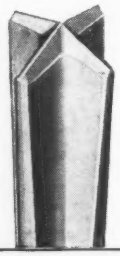
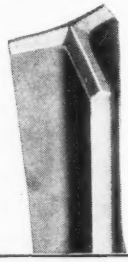


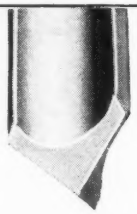
DURIUM MASONRY DRILLS

For use in hand and electric drills for Rawlbolt sizes C to G.

TRIFORM DRILLS

For use in electric hammers for Rawlbolts sizes C to K.





DURIUM HAMMER DRILLS

For use in electric hammers for Rawlbolt sizes C to J.

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For use in pneumatic hammers for Rawlbolt sizes E to K.

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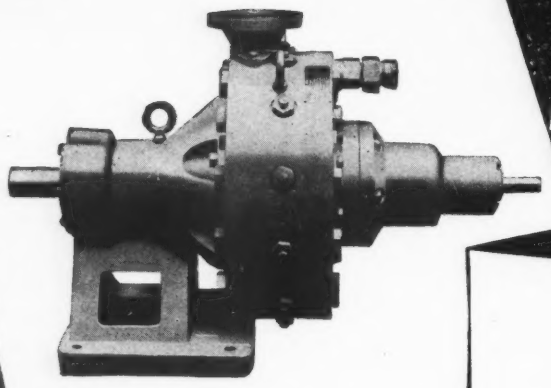
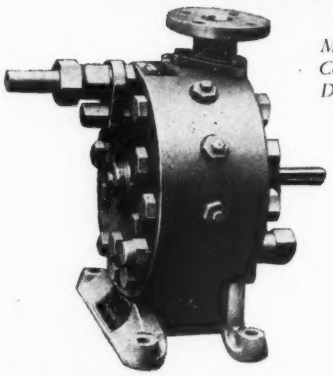


Mono-Radial Variable Delivery



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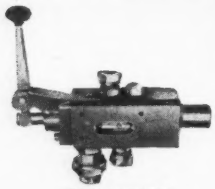

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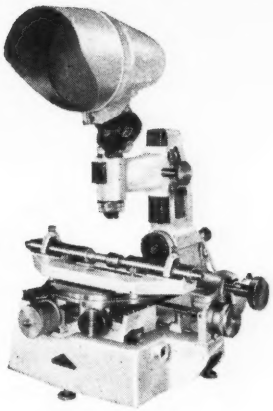
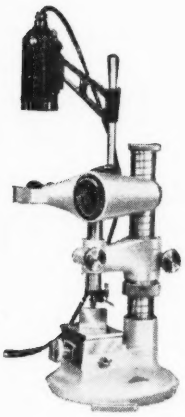
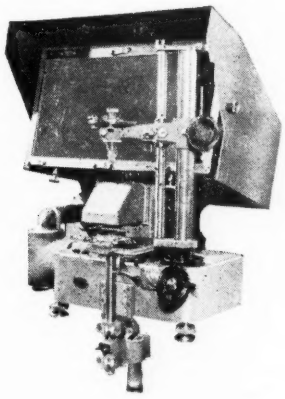




VERTICAL OMTIMETER

A precision comparator designed for the measurements of length thickness and diameter on all types of work. Readings taken to 0.00005" direct, 0.000025" by estimation. Finer scale reading to 0.000025" can also be supplied.

Capacity: Max. height of work 7"—Max. diameter 6".



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Magnifications 10 X, 30 X, 60 X or 100 X with fields of view from .6" to 060".

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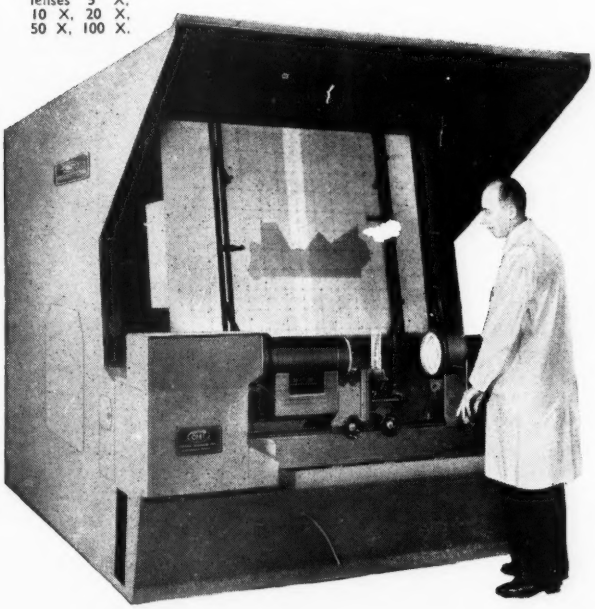

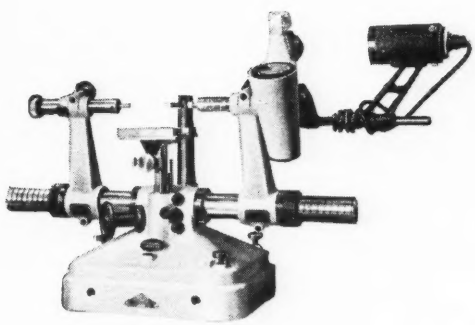

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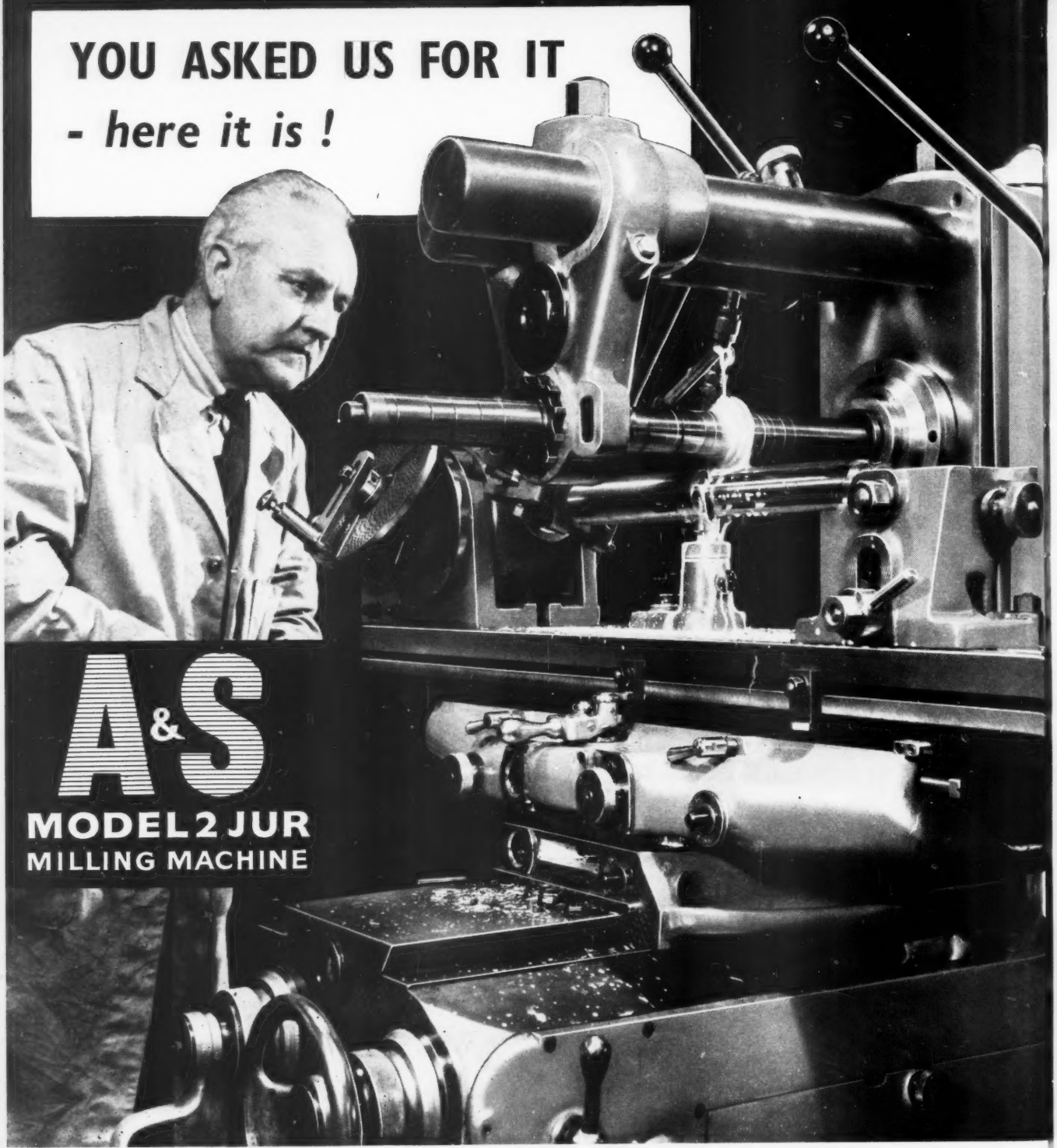

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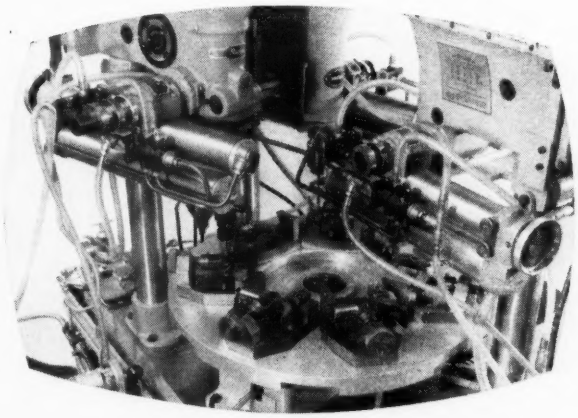
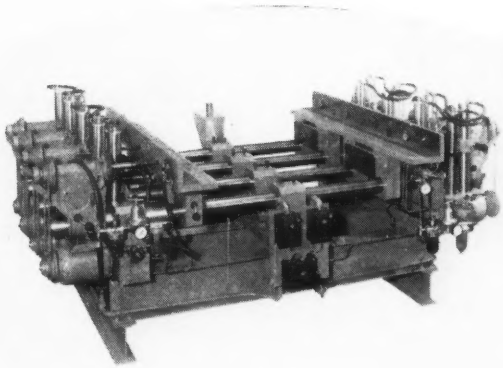
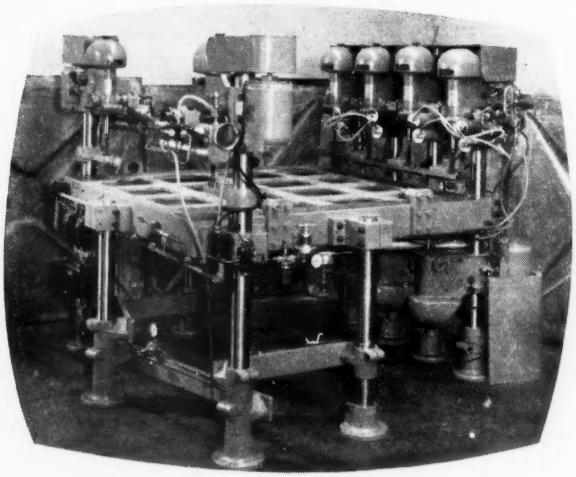
means automation by compressed air. And it means production *up* and costs *down!* Some examples of AIRMATION are shown where MAXAM control valves, cylinders etc., are used for moving, clamping and sequence control on special purpose machines designed and made by PACERA (W. J. Meddings Ltd.), by whose kind permission the illustrations appear. Can our Technical Staff help *you* with AIRMATION?







Above right: A machine for drilling 16 holes in a 54 in. x 52 in. component. 8 heads at 12 in. centres operate simultaneously. Component is automatically moved to next station and the operation repeated, leaving 16 holes at 6 in. centres. Floor to floor time 47 seconds; previously, the operation required 15 mins. 10 secs.

Above left: Progressive drilling followed by tapping on a special Hammer Head. Three operations performed simultaneously and in sequence with automatic table indexing. Floor to floor time 33 seconds; previously, the operation required 2 mins. 15 secs.

Below left: A machine for drilling 18 holes in a 54 in. x 52 in. component. Firstly 8 heads directly opposed at 6 in. centres operate simultaneously. The component is rotated through 90 deg. when 10 heads again operate to complete. Floor to floor time 47 seconds; previously, the operation required 15 mins. 10 secs.

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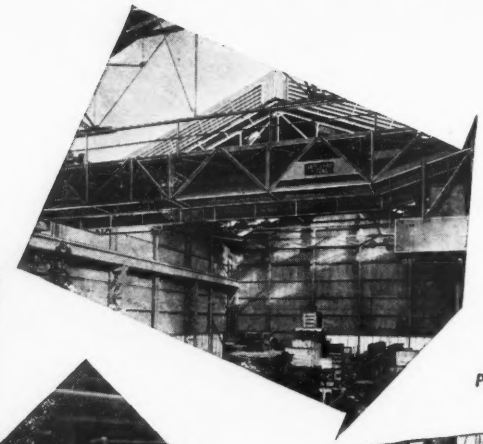
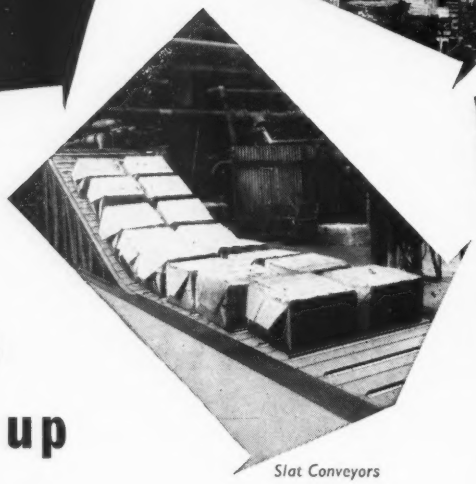


Electric Overhead Travelling Crane

Push Bar Conveyors



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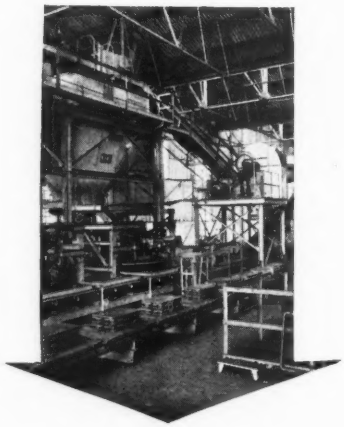

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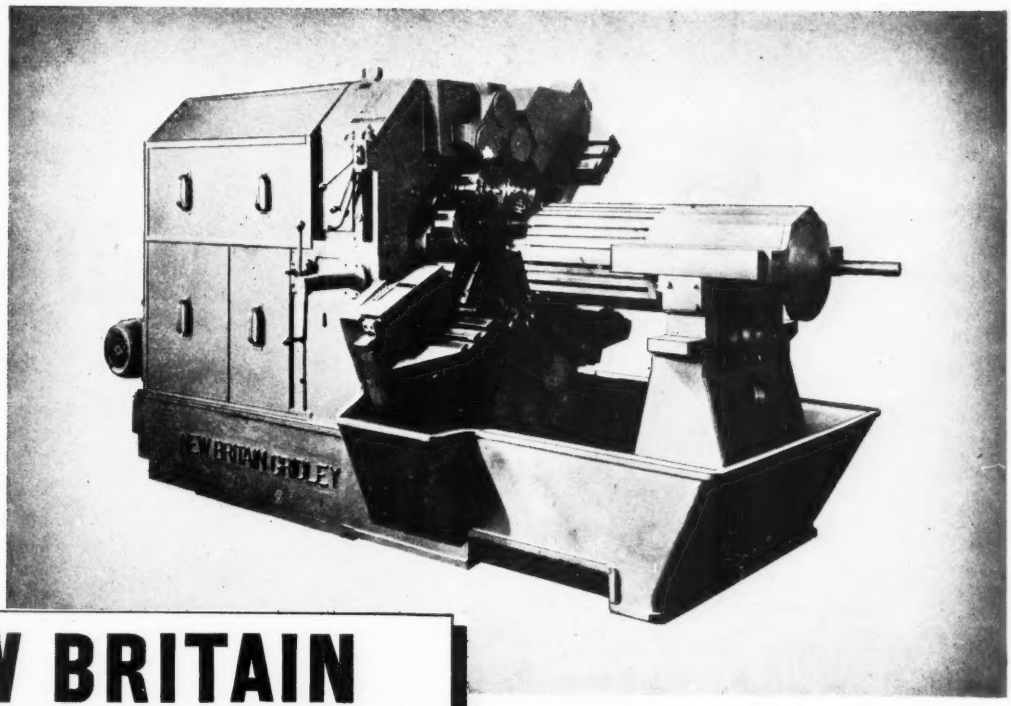

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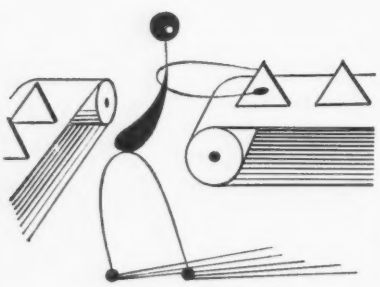
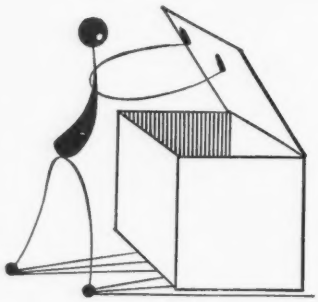
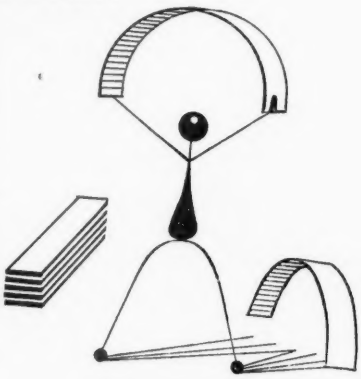


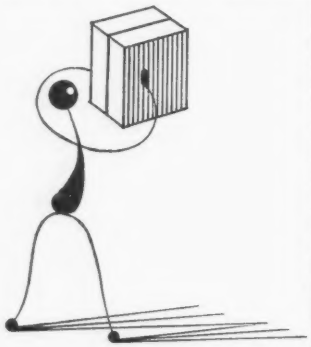
...transfer...



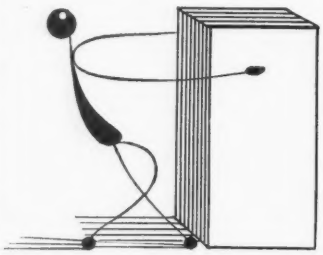
...open...



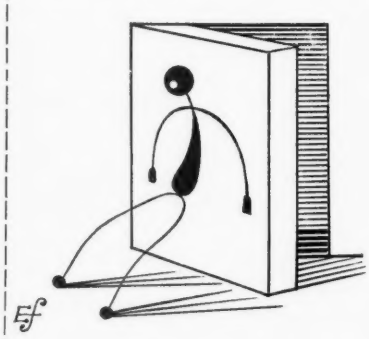
...bend...



...clamp...



...pull...



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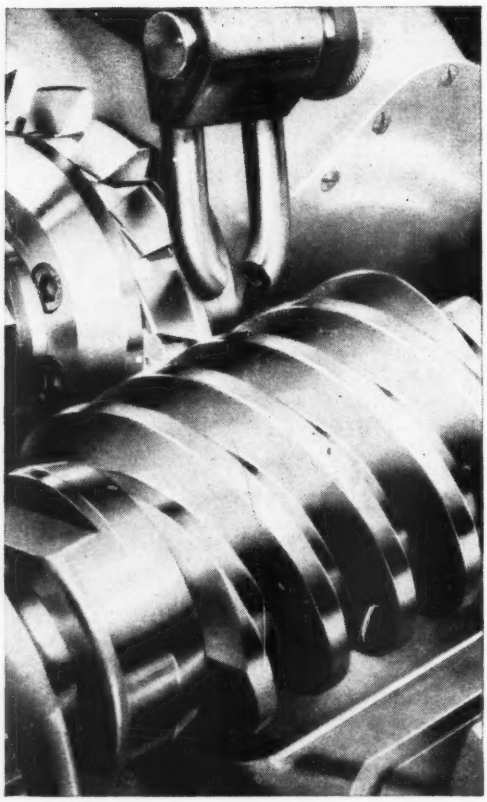

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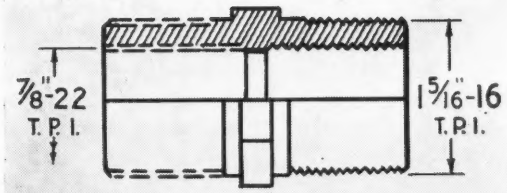

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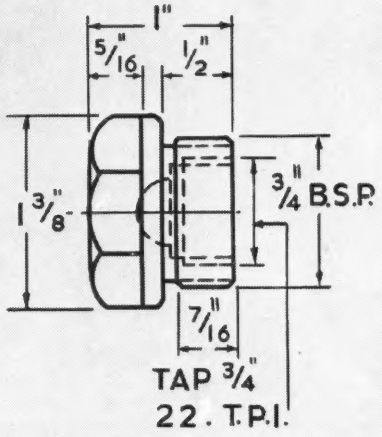

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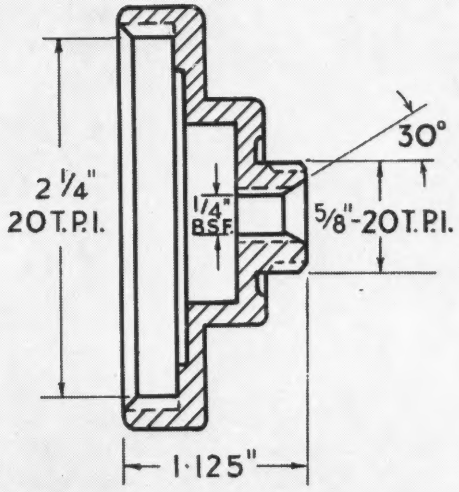

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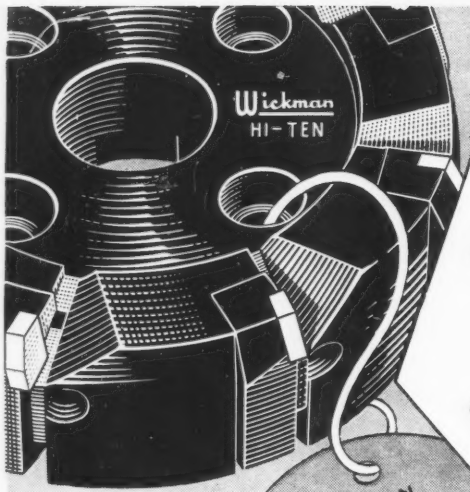

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The Supply of Students for Technological Education

An address presented to a Conference of the Association of Scientific Workers in December, 1956.

by Dr. J. TOPPING, M.Sc., D.I.C., F.Inst.P.,
(Principal, Acton Technical College)

MANY of our industrial scientists and engineers come from the universities, but the technical colleges are also closely concerned with the education and training of technologists. In thinking of the demand and supply of technologists, it is worthwhile to review, therefore, what has been happening in the technical colleges recently.

Immediately after the War, large numbers of ex-Service men, whom the universities could not accommodate, joined full-time degree courses in the technical colleges. The larger colleges had more full-time degree students than ever in their history, and the contribution they made, in this way, at a time of acute national need is widely acknowledged.

A Significant Fact

But in the last five years the number of such students have fallen steeply and some colleges have not been able to maintain the courses, whilst others have done so only with difficulty. This is perhaps not surprising in a period when the university population was much higher than it was before the War (in some scientific and technological departments there was a four-fold expansion), and also when the number of young men and women in the university entrance age-group was lower than for a century. However that may be, the significant fact is that even if the universities today are full or not quite so full, the technical colleges as far as full-time degree courses are concerned are empty. These degree courses in technical colleges act as a sort of barometer recording the pressure on available university places. They indicate, I think, roughly that all the students who at present wish to go to the universities are able to get in, and this is supported by other evidence. This does not mean, of course, that technical colleges are not making in other ways a considerable contribution to the number of graduates in science and engineering. The report on "Scientific and Engineering Manpower in Great Britain" tells us that "today the annual gross flow from the universities and technical colleges is a little over 10,000 in the sense of people taking first degrees or equivalent qualifications — about half of these are scientists and half engineers. *Of the latter under half are university graduates.*" In fact, the number of university students who in 1954-5 obtained a first degree in science was about 4,200 and in technology (including diplomas) about 2,800 — a total of about 7,000. The difference between this and the 10,000 just quoted does leave a 'considerable contribution' from the technical colleges, which is made up from three streams: firstly, the full-time degree courses referred to earlier; secondly, part-time degree courses; and thirdly, full-time and part-time courses of other kinds which lead to professional qualifications of graduate level. It is common knowledge that ever since their inception technical colleges have organised *part-time* classes, both in the evening and during the day, on which industry has depended for the training of its workers — at all levels. Through Higher National Certificate, Higher National Diploma, as well as degree and other

courses, thousands of those in technological posts today have qualified and achieved professional status. Many more, of course, have been trained as technicians.

No one, least of all technical teachers, would underestimate or wish to minimise the achievement of those who have come up 'the hard way'; industry could not go on without them. But it is increasingly obvious that the system of 'night-school and part-time day release' is not adequate today, and quite incommensurate with the magnitude of the problem which faces this country.

It is true that we are relying less and less on evening instruction only, and firms are increasingly releasing their apprentices to attend technical college courses on one or more days a week. *But more is needed.*

Development of Sandwich Courses

One striking recent development is the increase in the number of *sandwich courses* organised by technical colleges in co-operation with industrial firms. There are many types of sandwich courses, but at the highest level they usually extend over four or five years, the students spending six months in the college, followed by six months in industry each year. Entry is normally at about 18 or 19 years of age, for those who have passed in appropriate subjects in the General Certificate of Education examination at the Ordinary and the Advanced levels, or have passed at a sufficiently high standard an Ordinary National Certificate examination. The entrance requirements are roughly equivalent to those for admission to a university. Most of the students are already in industry, as student-apprentices, and so are termed "works-based", but "college-based" students, entering the college straight from grammar or public schools, can equally well be accepted.

Students who successfully complete recognised courses of this kind will qualify for the Diploma in Technology, an award to be granted by the National Council for Technological Awards. This Council has been set up by the Minister of Education with Lord Hives as Chairman, as an independent self-governing body responsible for creating and administering technological awards of high standing. Indeed, the courses leading to the Diploma in Technology are intended to be equivalent in standard, if different in many ways, to honours degree courses of a British University. The Council is at present busily engaged considering the applications from colleges for recognition of certain courses. From these courses many of the technologists of the future will come — in increasing numbers. It may well prove that this is one of the greatest educational advances of our time.

A Slow Growth

I will try to say something about *numbers* in a moment, but it is worth noting that until very recently the development of sandwich courses has been slow. A list of such courses published in 1953 showed only about 40 courses at 24 technical colleges in England and Wales, but by 1955 these had grown to about 100 courses at 44 technical colleges; not all of these, however, are likely to satisfy the conditions laid down by the National Council for Technological Awards. The courses are mainly in engineering but the range of subjects is widening to include the applied sciences. What is really significant is that in the last year or so the increase in the number of sandwich courses has been phenomenal. The causes are not obvious; they are partly social and partly economic, but the growth has been helped if not occasioned by a change in the educational outlook of some technical colleges and by the active support given by many industrial firms.

Perhaps I might be allowed to make a few comments on the supply of students for these sandwich courses, prompted by my knowledge of what has happened in a few colleges. How far they apply to the country as a whole I am not sure, but I think they are a useful guide.

Firstly, there is quite a large number of young men who leave our grammar schools and public schools at 18 plus, and enter industry as student-apprentices; they have passed the G.C.E. examination at the Advanced Level in two, three or four subjects, and many of them have university entrance qualifications. Firms are in general willing (and often enthusiastic) to allow them to join a sandwich course for the Diploma in Technology or for a university degree. (A university degree still has a great attraction for many of them and will continue to do so until the

Dip.Tech. has established itself). Of 59 students who have enrolled so far at one college, for sandwich courses starting in January, six have got four subjects at Advanced Level, 26 have three subjects, nine have two subjects and the remaining 18 have previously taken an Ordinary National Certificate course. Of the 59, 17 wish to take a degree course; 15 of the others have satisfied minimum university entrance requirements, but wish to proceed to a Diploma course.

Secondly, the numbers wishing to enter *engineering* courses seem to be reasonably large, certainly larger than those for *science* courses. It is much more difficult to start a course in applied chemistry and even in applied physics, than in mechanical or electrical engineering. Metallurgy and applied biology provide even greater difficulties. This is not surprising; the scientist is a comparative latecomer into industry and engineers are far more numerous than scientists. In addition, apprenticeship schemes and sandwich courses have long been a feature of *engineering* training and education, and it is not easy to persuade some people that such arrangements may well be extended to the education and training of applied scientists.

Thirdly, some firms (particularly small firms) have only very few apprentices (perhaps only one or two of a particular age-group) and consequently, though often willing, are unable to release them to attend sandwich courses. They would, however, usually like to double the number of their apprentices, if they were available, and have a "pair" for each job — one apprentice would be in College for (five or) six months whilst the other would be with the firm, and they would exchange places for the next (five or) six months. This "pairing" system, as it is sometimes called, is likely to be extended, but depends on firms being able to recruit double the number of apprentices.

Opportunities for Women

Fourthly, very few young women are employed as student-apprentices in engineering or research departments. There are opportunities for them, which perhaps parents and headmistresses do not fully appreciate. We have *one* young woman entered for the Diploma course in Mechanical Engineering.

Fifthly, besides the young men who enter industry at 18 plus there are many more who leave the secondary modern, secondary technical and the grammar schools at 16 plus. Of these some (a small percentage) take evening or part-time day courses in technical colleges leading to an Ordinary National Certificate. A few take a full-time course leading to an Ordinary National Diploma. The best of the students who obtain an Ordinary National Certificate or Ordinary National Diploma (perhaps the top 5 - 10%) seem to have the intellectual ability and the personal qualities which would suggest that they would profit from a sandwich course. It is good to find that many firms are willing to allow these young men to attend such a course.

Assessing the Supply

How are we to assess the supply of students available for these sandwich courses? There are two streams: (i) those coming straight from the Grammer and Public Schools immediately after the G.C.E. Advanced Level examinations, and (ii) those who have attended an Ordinary National Certificate course at a technical college and done well. Let us take these separately.

The number of students who *in 1955* entered for three or four subjects in the G.C.E. examinations at the Advanced Level was about 35,000; since an average of 70% passed in the subjects for which they entered it is reasonable to assume that about 24,500 passed in at least three subjects. The number who entered for two subjects was about 12,000 and probably about 8,000 passed. The number of students who entered the universities was about 22,500, leaving about 10,000 students who passed in at least two subjects and did not proceed to a university. Of these perhaps 6,000 took science subjects. How many are potential Dip.Tech. students? 2,000? 3,000? If it is lower than 2,000, we ought seriously to consider how the number can be increased.

Again, in 1955 the total number of Ordinary National Certificate and Diploma successes was about 14,000; the top 7% would give an additional 1,000 technologists. (I note that Venables records that 7% of the Ordinary National Certificate students

(*continued on page* 69)

THINKING MACHINES

by Dr. W. GREY WALTER.

Presented to the Institution at

the University of Bristol, 17th October, 1956.

Dr. Grey Walter

Dr. William Grey Walter, Director of the Physiological Department of the Burden Neurological Institute, Bristol, since 1939, *was born in* 1910, *in the United States, and was educated at Westminster School and King's College, Cambridge. He gained his B.A. at Cambridge in* 1931 *and his M.A. in* 1934. *He is a Doctor of Science and Honorary Docteur des Sciences Aix (Marseilles). He was Michael Foster student in the Physiological Laboratory, Cambridge, from* 1933-35, *and Rockefeller Fellow at the Central Pathological Laboratory of the London County Council,* 1935-39.

Dr. Walter founded the Electro-encephalographic Society and is President of the International Federation of E.E.G. Societies, and is co-founder, and Editor since 1949, *of "Electro-encephalography and Clinical Neurophysiology".*

He is the author of "The Living Brain", "Further Outlook", and numerous scientific papers on brain physiology and cypernetics.

THE title of this lecture contains two difficult words. "Thinking" has been used in many senses; for most people it is an exclusive attribute of human beings and for many it is almost synonymous with logical reasoning—the power to deduce relationships from formal propositions. In this sense, presumably, mathematics is the highest form of thinking, since in this domain communication can be unambiguous and explicit. The term "machine" also needs definition, having acquired a very specific implication during the technological revolution of the last few centuries, but we should remember that in origin the term is far less definite, and means only a way of doing something.

For the purpose of this lecture, thinking will be considered as something more than the ability to sort out logical deductions, and in the class of machines will be included not only the tools and ironmongery of our workshops, laboratories and factories, but also the more modest electric jelly which we carry about inside our heads.

During the last ten or twenty years this pinkish jelly, the human brain, has been studied with increased intensity, thanks to the legacy of technical devices from the war. Until recently, study of the intact human brain was hampered by the lack of means to record and analyse many variables at the same time; this limitation is not a special one but applies also to the study of any complex system, whether living or not, and problems relating to such systems are now being very actively investigated under the generic term of "cybernetics", which Wiener has defined as the "study of control and communication in animals, machines, and Society".

The attitude of mind suggested by the term "cybernetics" has been criticised in many ways; the most justifiable perhaps being that it encourages

facile comparisons between living and artificial systems. For example, the working of a human brain has often been compared with that of a computing engine and contrariwise such instruments are often referred to as "Electronic Brains". In this particular case the comparison is indeed superficial and even misleading; it may be based on the definition of thinking, since if this term is restricted to logical processes, then indeed the modern computing engine can perform at least as well as most human brains—but of course it remains to be proved that the procedure is the same in both.

A computing instrument can select and classify logical propositions because, in the vast majority of cases, such machines are designed to classify information in terms of "yes" or "no" on a binary scale and this is both necessary and sufficient for the general class of logical propositions. If, however, we consider thinking as depending also upon a sort of statistical reflection, we can see that the analogy becomes less convincing and in our computing engine we must include some sort of analogue device with the functions of a *totalisator* which will cast the odds in terms of "perhaps" and "think again".

On the other hand there is some physiological justification for comparing the nervous system with the binary or Boolean classifying system, since the nerve impulses that convey information between the brain and the outside world and within the brain are in effect binary processes—in physiological terms they are "all or none". As a corollary, the transmission of information along the nerves is accomplished by a system of frequency or pulse-interval modulation which, as all the engineers know, is a convenient code when there is danger of random changes of amplitude and cross-talk. However, the more closely we study the intact human brain, the less impressed we are by the binary features in its transmission system. We may be entirely mistaken—for such investigations are still in their technical infancy—but the evidence available at present suggests that, however rigorous may be the binary coding of nerve transmission in nerve fibres within the brain where the nerve impulses reach great populations of nerve cells, there is a conversion to analogue processes. One might perhaps compare this with a voice transmission line using a binary code such as a vocoder, which none the less is terminated in an analogue device such as a loud speaker.

In designing such a system an engineer would have to take great care that he was not saddled with the faults of both systems and he would aim to take advantage of the virtues of both. We may suppose that during the millions of years of animal evolution, a good compromise has been reached so that the faults inherent in the binary and analogue systems have dwindled to secondary importance and their advantages have been exploited to an amazing degree.

Quite apart from academic and highly technical observations, we may look within ourselves and consider whether we are inherently capable of logical reasoning without practice and discipline or whether, on the other hand, we are more prone to follow unconsciously elaborated hunches and intuitions. Looking around at our present-day society, I have the impression that thinking of the first type requires enormous effort of concentration and can be achieved really only by a very few people, whereas we all live largely in the second mode, whatever our culture and motivation.

The investigation of human brains does more than suggest analogies; it encourages us also to understand ourselves as a special sort of thinking machine; one of the first clear impressions we obtained is that similar though we may be in size and general structure, functionally the human thinking machine exhibits outstanding personal differences. These differences are familiar to us all as what we call "Personality" and "Character", and psychologists have for long considered this aspect of human mentality and devised tests and classifications in the hope of deriving an objective tabulation of personal characters.

Alpha Rhythms

As a physiologist, my own efforts have been directed along similar lines, to setting up some sort of tentative classification scale, based not so much on psychological tests as on recordings of the electrical changes which go on incessantly in all living brains. It is one of those paradoxes so frequently encountered in new fields of study that, contrary to expectation, the greater the degree of mental activity in the brain, the less prominent are its electrical discharges. This was first observed long ago by Hans Berger in Germany, and the reason for it is still by no means fully understood. It is, of course, surprising that we can record any coherent electrical activity at all from the intact brain, since it contains something like ten thousand million individual cells, all capable of continuous interaction with one another. Indeed many normal subjects do show a very random and irregular type of activity from all parts of the brain whatever their state of mind. Most people, however, seem to produce a surprising amount of rhythmic electrical changes, particularly from the back of the head where visual signals are integrated and processed ; these Alpha Rhythms, as they are called, are more regular and more prominent when the eyes are closed and mental activity is least. But they are modified in a profound and complex way when the attention is directed to a visual signal and in most people also when, so to speak, the mind's eye is active, that is, when the subject starts to think intensely in visual terms, to call up visual images for the solution of some problems.

Long study of these records, taken from hundreds of normal subjects, has suggested that in most people there is a well-formed set of thinking habits which seem to depend upon the way in which the brain tends to direct attention to a particular set of incoming signals. Even when no information of interest is arriving from the outside world these habits seem to persist in thinking, so that a person who lives mainly in a world of things *seen* will think mainly in terms of things that *might* be seen. He has, in simple terms, a vivid visual imagination and uses it to find his way around and to plan his actions. Others again pay

more attention to the world of sound or movement and think in terms of words or gestures or even in dance patterns. Others again seem to have a capacity for almost abstract thinking in which images are of a formal and less material character.

As far as we can tell, these patterns or habits of thinking depend mainly on inborn characteristics and are difficult to modify by training or experience.

What is Worth Learning ?

We are at present conducting a series of experiments designed to discover how these inborn characters of imagination are related to the way in which people learn, and in particular how people decide what is *worth* learning. A moment's thought shows that in human affairs some such selection is of primary and fundamental importance, not only in such mundane and well recognised problems as choosing a career but also in the more subtle and more influential decisions which build up a personal philosophy of life. We know well, perhaps too well, that there is great variation in our philosophies of life. To this we may attribute many of our conflicts and social catastrophes, but it is one of the lessons that study of the brain may help to teach, that these differences are part of our biological inheritance and we must learn to accept and enjoy and exploit them to their uttermost—for in effect they are all we have that is truly human and our Society can only live on and with those personal differences. I shall be suggesting later that the great range of personal variations which we know so well in ourselves is the inevitable outcome of interaction between a complex goal-seeking system and a complex environment. I would suggest furthermore that the more complex the system, the greater variety we should expect between individuals and perhaps the greater inherent instability in a population of such individuals. As a corollary, again, the larger the social unit the greater the chances of local instabilities; there is even some suggestion that, as in the case of the size of animals, so in society there may be a fairly well marked optimum size for communities. Whether the factors determining this optimum are as simple and rigid as the square-cube relation between strength and weight that limits our physical dimensions, remains to be discovered. The relation may be less intricate than we fear, but we have not even reached the stage of precise measurement, let alone of computation.

Even now, however, we are gaining some hints of how the personal characters of human brains may influence the way in which social groups aggregate and dissolve, and how the differences in ways of thinking may be studied and perhaps more fully exploited. These investigations are still at a superficial level and we are in considerable difficulties already in dealing statistically with a mass of multidimensional information.

As a first step, we have endeavoured to classify our observations of human beings so as to arrange them in some order on rather arbitrary and not too well-defined scales. These we have called by such names as Imagery, Versatility, Ductility and so forth. On the Imagery scale, we have those differences already referred to in the ways in which people prefer to solve their problems; we have noticed that similarities in this respect make it relatively easy for people to work together since they speak, as it were, the same mental language, and this may form a basis for mutual attraction and appreciation. In the limit, however, such similarities or affinities may be oppressive, in the sense that two people who think and reason in the same way are unlikely to correct one another's mistakes. Besides, it should be remembered that the agreement is as to means rather than ends, and if two people are accustomed to agree without difficulty in their *ways* of thinking, they may find themselves in particularly tiresome conflict should they reach a point of disagreement about their conclusions or their aims.

Considering the converse case of people with diverse ways of thinking learning to work together, here there may be mutual complementation and error correction, but our observations suggest that people who differ in this way may take a long time to appreciate one another and will tend continually to irritate and provoke each other in a special way. The effect may be to exaggerate, even caricature, the outstanding features on both sides, but here again the difficulty in understanding one another's methods of thinking may be more than compensated for by sudden insight into an essential agreement on purpose.

These generalisations would all be trite and trivial were it not that such relationships can be plotted in objective terms on a basis of brain activity—it is no slur on such interpretations that they merely confirm and amplify the impressions of everyday life. If they did not, the incongruity might be a challenge but could scarcely be directly helpful. What we hope is that familiarity with the impressions of everyday life as presented and measured in this form may help us to realise what other information our records display, and how this may be incorporated into a physiological approach to human mentality and society.

An Intriguing Problem

Whatever source of information an individual brain may prefer to use, the information must at some stage be filtered and selected. No brain is capable of dealing with all the information all the time, and indeed quite simple experiments show that only a small proportion of the available sensory signals from the eyes, ears and so forth has any effect on the brain; some signals indeed probably never reach it at all. They are rejected before they even influence the nerve fibres leading to the central grey matter. This is perhaps one of the most intriguing and intricate of all brain problems. How does a nervous system "decide" what information is worth accepting? How does it classify the acceptable information? How does it store the relationships extracted from individual signals? How does it use this stored abstraction to build up a working model of the outside world and itself, and how from all this does it rehearse and plan appropriate action?

Most of the processes thus encountered are included

in the category of learning and this is a subject now being studied with great assiduity in many laboratories, not only from the standpoint of the psychologist and educationalist, but now at last with reference to the mechanics of brain function. Here again we have to resort to rather elaborate techniques. We cannot hope even in our wildest dreams to match the complexity of our equipment to that of the brain itself. Even if we ignore the already vast figure of ten thousand million for the number of brain cells and assume, as we may be justified in doing, that the functional unit contains many thousands of individual cells, the number of permutative combinations of these clumps of grey matter is still far larger than the number of particles in the visible Universe. So we must be content to limit ourselves to inspecting a very small sample of the total activity.

The Technical Details

For those who can appreciate technical specifications, the records from which we are beginning to learn about learning are taken with 22 channels of amplification derived from 16 points on the head of our subjects. The small potential differences are then displayed on a cluster of cathode ray tubes, the signals being here represented as changes of brilliance, much as in a television set. The scanning system consists of a spiral trace which, with a variety of servo-mechanisms and recording devices, has the effect of indicating in a visual manner or on a set of developed photographs the auto-correlated and cross-correlated electrical activities in all the 22 channels. Together with this system there is also a direct ink record in terms of voltage with respect to time and an automatically derived wave analysis which approximates to a frequency spectrum of the rhythmic electrical activities. In addition to this, again there are records of the stimuli presented to the subject and of his responses and also of the changes in his unconscious and uncontrollable functions, most of which are related in some way to his feelings and emotions rather than to his reasoning.

As in the case of the spontaneous rhythmic activities and imagination our first impression is of vast personal difference. Our aim is to plot the course of learning in the subjects studied in this way, and unlike some laboratory experiments we have tried as far as possible to imitate the conditions of normal life, though in a miniature and relatively monotonous situation. In spite of these limitations no two subjects are alike and the degrees of freedom are so great as to discourage any facile general description. The only clear light at the moment is that we have been able to set up for testing a fairly rigorous and detailed hypothesis about the stages necessary for learning within the brain and it seems feasible to subject this hypothesis to experimental trial, even though the necessary conditions are more complex than any of us have been trained to handle.

The essence of this theory of learning is that in the first and basic step the subject must make some decision about the importance of the various signals which he receives. He is given no instructions about this nor any hint as to the best procedure to adopt. Our theory states that in such circumstances his best bet would be to treat the stimuli or signals as the data from a statistical experiment, to make no *a priori* hypothesis about their relationship, and take no action until he had acquired sufficient data for a reasonable estimate of significance to be computed.

We are thus considering the brain as if it were an analogue computer designed to make progressive estimates of contingency between various sets of events. We are suggesting that a human being cannot "make up his mind" until, in effect, his brain has made up a table of correlations or contingencies. The experiments themselves are accordingly designed to submit the subjects to various levels of significance in the relationship between the stimuli. In this way we hope to discover not only whether some such process of statistical sorting is going on, but also what are the criteria of significance accepted by the brain and how these criteria vary from one person to another and in the same person in different situations.

It should be mentioned, perhaps, that in experiments of this type there are both "conscious" elements in that the subject is subjectively aware of most of the signals and can describe some of them quite accurately, and there are also "unconscious" elements, that is, features of the situation which none of our subjects seems to have noticed consciously but to which nevertheless they often respond both aptly and regularly. This, of course, is related to the recently popularised, but long-known effects, of so-called "subthreshold" stimulation, in which a signal may influence a person's behaviour without his being consciously aware of its existence. It is obvious that the term "threshold" so often used in psychology and physiology is hard to apply literally in the case of the intact brain, since the mechanisms of the nervous system which mediate action are influenced not by single events, but by relations between events, and the threshold of a relationship is at the best probabilistic and at the worst may tend toward an infinite regress—a relation of a relation of relations. . . .

We have no doubt, of course, that the concept of thresholds is of the utmost importance in understanding brain activity. In more general terms, we have to incorporate in our hypothesis an indefinite number of non-linear operations; as far as I know, there is no familiar and well-tried mathematical tool for dealing with such problems and we have to feel our way by experiment and conjecture.

A Difficult Position

From what has been said already, it will be obvious that we are in a difficult position in our attack upon the mechanics of brain activity. A scientific approach to this subject can easily become so beset with vague and mystical beliefs—or on the other hand with crude mechanistic analogies—that mutual understanding is lost and personal prejudice alone survives. The difficulty of devising algebras for such problems encourages the elaboration of verbal hypotheses, containing only ambiguous and more or less provocative phrases comparable with the ancient and now

ridiculous assertion "the brain secretes thought as the liver secretes bile".

Many of the tangles that language ties itself into when suddenly cut off from observation are due to our almost compulsive use of abstract nouns such as "mind" and "thought". I may be deluding myself, but I find thinking about these matters less turbulent if I ration myself very severely in the use of such words and employ rather the corresponding participles or less emotionally charged abstractions. Thinking is easier to think about than thought, and mentality is nearer to experimental observation than mind. We are not bound to use words because they are to be found in a dictionary and nothing confuses thinking more than to "hypostatise it into an entity". More obviously, vernacular phrases are deliciously ambiguous and the meaning attached even to the most respectable word may change almost imperceptibly with use and argument, until even the user is uncertain what he means. How many scientific discussions end up in philosophical despair with the notorious surrender cry of "it all depends what you mean by —"? In another generation, no doubt mathematical tactics will have been worked out to invest and invade this territory. At the present time, even those equations which have been proposed and employed in limited patrol actions and reconnaissances are beyond the comprehension of most experimentalists. It is one of the problems for teachers in our schools and universities to impart to scientists of to-morrow that combination of experimental enthusiasm and mathematical elegance which inevitably wither away in present curricula. Perhaps this intellectual revolution can come about only with the aid of man-made thinking machines—this we will consider later.

The Use of Working Models

In the meantime, betrayed by the poetic flexibility of our language on the one hand and by the stiffness of our mathematical tools on the other, we have still one modest stratagem to communicate ideas about thinking without giving too much or taking too little of one another's confidence. This stratagem is the use of working models; I have called these "crystallised hypotheses" because ideally they should be clear and limited in their domain and within their restricted field of operations, brittle. If in the testing they fall short of expectation or reality they do so without equivocation. The model hypothesis cannot bend or flow—it breaks with a loud crack—and from the pieces one can build a better model.

The building of models to imitate various conjectures is as old as science and older than logic, but this is the age of working models because technically we can accomplish what our ancestors could only dream. Some of you may have seen the clockwork automata made by the inspired Swiss watchmakers of Neuchatel. Seeing them in the light of present knowledge and ideas, one is struck not only by their mechanical elegance and durability, but also by their metallic reflection of contemporary rational determinism. There is really no reason why clockwork should not be given the freedom we accord to our electronic models; perhaps there is something about a spring and a gearwheel which is more constricting to the imagination than a battery and a vacuum tube, where the working parts are invisible and in the last analysis, scarcely "real".

In any case, during the last ten years or so, many models have been built to display notions of how the nervous system may work. It would be interesting to review and compare all these various models but this is a major enterprise. I may now only ,perhaps rather provocatively, assert that all these models are in a sense convergent, and in their various ways embody grains of truth which, cemented together by further experiment, could become a solid raft to sink into the clay of living mysteries. Here we have time only to consider a few which have grown from the doubt and despair we sometimes feel in matching our wits against themselves.

When one sees these synthetic creatures in action, one can at least make up one's own mind about the extent to which the characters of living creatures, which naïvely one supposed to be " essentially vital ", can be displayed without ambiguity by simple mechanical contrivances. If required, a machine can be purposeful, it can be discriminating and selective even with very few component parts, it can exhibit an amazing versatility of conduct and self-control. It can attend to its own breakdowns, protect itself from fatigue and exhaustion and even design its own spare parts; in the future even prepare an improved model as its successor. We are so accustomed to thinking of even the most modern and elaborate machines in terms of our own needs and limitations that it requires some effort to consider them as collaborating in our fantasies and contributing to our future.

Nearly all mechanical models of animal behaviour have differed from utilitarian tools in one very important respect: their internal connections are not fixed or predetermined by their structure, but are left to the operation either of chance or the coherent and cumulative action of experience. In this, of course, they resemble ourselves and other living organisms; they inherit or are endowed with a certain given structure and design, but the way in which this arranges itself is not precisely predetermined and after such a machine has started work the constructor cannot say for certain precisely what its internal state is nor what its future behaviour will be. He may be able to guess with some assurance, but he cannot be sure. He has a pretty good idea of the sort of thing the machine will do, knowing as he must the limitations of its structure, but he is not certain just *how* any particular function will be performed nor whether any particular manoeuvre will be successful. As a tool, of course, such a machine would be as infuriating as a sorcerer's apprentice and as a toy it pleases only the most sophisticated children, since it is neither inert like a doll nor controllable like a model railway. In a sense it is feral, as the law insists cats must be, but it can solve dilemmas that only philosophers define and express equations that only mathematicians understand. Such behaviour is produced most

easily by the provision of a small and known number of internal components which are free, within the limits of survival, to connect themselves to one another in a large variety of patterns. Thus, two elements in a simple model of reflexive action can exist together in seven ways, and algebraic analysis suggests that very approximately for large numbers of elements, the number of modes of existence of such a system is equal to two raised to the power of the square of the number of elements. This is obviously an explosive series, and if we relate this concept back to the human brain we may be shocked to realise that if each individual nerve cell within our heads is an element in the above sense, then the number of modes of existence in the repertoire of our brain patterns would be something like two raised to the power of ten thousand million squared. No wonder that even our crude electrical records impress us with their individuality and versatility!

Reflexive Machinery

So far we have discussed only what physiologists would call "reflexive machinery". This term I consider a good one, better in some ways than the rather casual "feedback". Physiological studies of reflex action came before the engineers thought of negative feedback, and the reflex is as complex as we care to make it whether in the flesh or the metal; but a reflex system does not learn. At least I would prefer to define a reflex system as one which does not change its responses in the light of experience.

It is true that a simple machine with a couple of reflexes can adapt itself to a fairly complex environment in a variety of ways, and it may succeed in modifying the environment itself, so there is a constant interplay between the internal rearrangement of the organism and the more inert but still plastic features of its surroundings. This should inspire us with caution, for such a process often looks like something very special. It may mimic learning to a remarkable degree—but I think it would be confusing to call it so, for this process is not really so different from the way in which a river wears away its channel or an engine turns more smoothly when it is run in.

The progressive mutual adaptation between a reflexive organism and its surroundings resembles *wear* more than thinking and furthermore it is in general a sequential computation of mismatch. There may, of course, be many reflexive operations going on simultaneously—indeed, there must be in any animal —but their relation is only partially integrated and they are often in open conflict. In the models we have played with, this difficulty has been overcome—not so much by design, I am ashamed to say, as by an unconscious desire for complexity—by the insertion of a scanning mechanism.

A rather similar result might be achieved by a noise generator, that is, by some mechanism that added a random component to the creature's systematic response to stimuli. It is a nice point how these two systems would differ. We have seen that a system with a space-time transformer, that is a scanning device, can solve automatically some of the tedious dilemmas which otherwise it would find insurmountable: presented with two equal stimuli it does not fall between two stools, but will seek first one and then the other. A creature similar in other respects but endowed with a randomising element would avoid sterile compromise, but would it do so more or less quickly? Would it have still further potentialities or other limitations? This is a point for discussion and it may be of great importance in considering the nature of higher nervous activity.

We may now envisage in the world of machines the property which most intrigues us in ourselves—the capacity to select significant relations against a background of random ones. There are several ways in which this can be done with hardware. Again, some depend upon a systematic attitude to time relations and others make use of random potentialities. In the machine I have used for crystallising my own hypothesis, a fundamental assumption is that the distinction between significance and chance is a *statistical* operation and, furthermore, that the relationship between events must be classified in terms of their order as well as of the correlation between them. For example, if we consider the nature of thunderstorms we must be able to recognise that lightning always *precedes* thunder. It is not the correlation between them that leads to speculation about the velocities of light and sound but the *order* of their occurrence. Sooner or later an animal must extract some notion of causality from its experience, and to a first approximation he must accept the axiom that an event cannot be caused by its successor. On a purely empirical basis we know that this is not necessarily true; we may receive from a distance information about an effect before we are informed about the cause—but such exceptions do literally prove the rule, for in the face of such anomalies we usually prefer to investigate the situation with particular care and thus define by experiment what an empirical paradox might have turned into a superstitution.

With these two assumptions about how animals learn to behave rationally and effectively, machines can be made to perform similar operations. The one which I have described requires no less than seven functional elements to achieve the desired result and I claim that some such arrangement is necessary, but I admit that the way in which each operation is performed is a matter for further discussion and experiment.

A Criterion of Significance

In working out the details of the design, one immediately encounters a very interesting problem. If the sorting out of relationships between signals is to be based on a probabilistic philosophy, there must be some *criterion of significance*. In our example of the thunderstorm we may say that lightning always and only precedes thunder, but few relationships are so simple and invariable. There may even be malicious competitors or bystanders whose aim is to confuse our view of things. They may deliberately invert or suppress or corrupt the information we get; they may even deliberately fabricate propaganda and fairy stories. What standards of significance should a

reasonable animal have? Can we define a reasonable animal, as the law has so often tried to define a reasonable man? There is a very wide range of choice here. In the old easy days of my apprenticeship, statisticians agreed that a relationship between observations was likely to be significant if the odds were greater than 20 to 1 against it being observed by chance. More recently the odds have lengthened and we have to quote about a hundred to one to obtain the support of our colleagues. Most animals are even more sceptical than professional statisticians—but of course they have more to lose. The penalty for taking odds of a hundred to one and coming out on the wrong side of the book is only a peppery correspondence in "NATURE", but when life is at stake most animals seem to be far more cautious.

Analysis of results obtained from experiments in training animals, combined with the sort of chances we ourselves accept in everyday life, suggests that higher animals are reluctant to commit themselves to action until they have enough data to suggest that the relationship concerned is improbable by a factor of between a thousand and ten thousand to one. This is still a very wide range, but it is here that we see in a simple principle one of the basic factors in personality. All animals are sceptical, but some are more sceptical than others.

We do not know whether the same sort of factor is applied by an individual animal to all situations or whether there is as wide a variation between situations as there appears to be between individual animals; probably there is, and indeed we know that in our own lives we will take chances in one situation which we reject instantly in another. Here, of course, we begin to appreciate what psychologists mean by incentive. (I have studiously attempted so far to avoid using psychological terms. We cannot avoid their anthronomorphic implications and I am convinced that my duty as a physiologist is rather to make what observations I can with the techniques available, and from them to build up a set of parameters and axioms, without making any assumption about their relation to the traditional and classical psychological expressions.)

We know well that if an animal has a voracious appetite it may be driven by the prospect of intense satisfaction to hazardous action, and we know too that confronted with a more formal situation the same animal must be persuaded by starvation and systematic reward to accept the conditions imposed by the trainer. Further again, it is a familiar fact that rewards for obedience and punishment for insubordination can usually be combined with good effect. From all this we may conclude with wisdom that to generalise about an animal's probable attitude to any situation in terms of its preferred canon of significance would be too facile; none the less there is much experimental evidence that an individual animal of a certain species tends to operate only over a certain range of probability and we have some reason to believe that this factor again, as in the case of the nature of imagination, depends to some extent upon inborn brain characters.

We have observed that in certain classes of our human population there are peculiar characters in the electrical activity of the brain that seem to be associated with a tendency to take what most of us consider unjustifiable risks. The feature of brain activity which has impressed us in this way is the presence of slow electrical changes, at about one-third the rate of the normal alpha rhythms, which are rather like those we find in greater prominence in babies and in deep sleep. In a sense people with this character are immature or juvenile. They are happy-go-lucky and easily led. We call this character trait "Ductility". This tendency to take long chances even when the luck is against you is found in a large proportion of young delinquents, particularly those with a long history of petty offences. It is also found in many people whom we regard as unusually courageous, for example, those who habitually fly modern aeroplanes from aircraft carriers, parachutists and skin divers.

I am not suggesting that in delinquents and courageous adventurers there is *nothing but* this factor of ductility; obviously there are many other factors but it may be that these groups have a great deal in common. In our society it is necessary that there should be people who are anxious to break rules, just as there must also be people whose ambition is to make them. I mention this here because the impression most people get from comparisons of machines and men is that inevitably the romantic and imponderable aspects of human life are filtered out and thrown away by mechanical comparison. This is not necessarily so, for the study of machines designed to imitate some rudimentary features of human behaviour throws into glorious relief the variety and potentiality of the human inheritance.

A Personal Reaction

For me personally there is another effect which you may not feel so intensely, since most of you are committed to a vocation in which control of people and machinery is an essential part. Studying machines and the living brains which they are intended to mimic, I am impressed by the elegance and integrity of the inborn differences between people and I feel even more reluctant than before to try to meddle with them. It is platitudinous that we should not try to control what we do not understand. I find a deeper satisfaction in restraining myself from interfering with mechanisms which I am beginning to understand a little.

To return to the hypothetical mechanisms of learning, we may distinguish conveniently between the operations in a learning machine which are essentially *selective*, those which, as already described, filter out from a mass of confusing and random signals those which have a significant relationship, and on the other hand those mechanisms which *store* information thus accumulated.

In the particular machine I am using to illustrate this discourse, there are three storage systems. The first of these to be activated acts merely to retain for a certain time the information that " something has happened", in case something else should happen shortly afterwards with which the first event might later turn out to have a useful relationship. The

second store accumulates information about the degree of overlap between two series of events. Already at this stage the material in the store is far removed from the outside world. In the model it is actually a charge on a condenser, which leaks away very slowly between experiences so that, if they are too few and far between, the storage register can never fill up and the machine will ignore (in the French sense of the word *will not know about*) events that are too infrequent to be of much consequence.

The third storage system is more like what is usually called Memory, because it is activated only when the second store is full to the brim and spilling over, that is, when the criterion of significant association has been satisfied. In effect, this third storage system contains only one bit of information, that the relation between one series of events and another has exceeded chance expectation; a statement which, given the criterion of significance, is either true or not true.

The change in behaviour which the series of experiences may produce can be released only by the operation of this third storage system. This again has important implications, for it is only after the instant at which this third degree memory is activated that there can be any outward sign of learning; until then a great deal has been going on inside the box or the brain but there is no sign of it in behaviour.

Once more we are tempted to compare this apparently abrupt transformation of behaviour with what the psychologists call "Insight". I have hoped and urged that this sort of analysis may help to bridge the gap between those who consider learning as a progressive reduction of error by successive trials, and those who are more impressed by the abrupt solutions to problems which suggest insight. In my view and in my models these two processes are not merely compatible but inseparable companions.

In the experiment on learning I referred to at the beginning of this lecture, we are trying to test this detailed but explicit hypothesis by studying one another in learning situations while electrical changes in the brain and other parts of the body are being recorded. These experiments are still in the technical stage, but we already have some evidence that in its main outline at least the hypothesis is reasonable. The electrical changes produced by various experiences in the brain do seem to depend upon the significance of the associated signals in the statistical sense already defined. Information reaching the brain from the eyes and ears is very widely, but rather slowly, diffused through a great part of the brain structure—rather as in a well-organised office, letters may be copied to many Departments "for information only". Sometimes we can even see traces of the storage mechanisms of the brain and we are not surprised to find that nearly always the pattern of the outside world is represented in a distorted form. We know that all messages reaching the brain are corrupt, but messages from two sources are doubly corrupt and in some people the corruption extends even into the field of action; some of our normal subjects and many patients are liable to generate in their brains fantastic caricatures of the signals we send them and some even succumb to something like an epileptic seizure if our stimulation is very regular, intricate and persistent.

Mental Failure

It seems, therefore, that in testing this hypothesis we can also test the human thinking machine, if not to destruction at least to reversible failure, and this already seems to have a valuable application in the field of clinical psychiatry. Everyone is perturbed by the high incidence of mental failure in our society. Few of you, I fancy, would be satisfied with a system of quality control that allowed 10% of your products to be issued in an unserviceable condition—yet this is about the rate of failure in human mentality. The cost is very high, and the prospects of improved management rather low. Are the standards required by modern and future society too high or is there a progressive decline in human resilience and understanding? Some wastage of course we must accept, but I have the impression that some of the troubles that plague our communities can be understood more clearly if we think of them in new terms. When we understand them there is a hope that conditions can be designed, not merely to lessen the stress on the more vulnerable types, but even to exploit in a new way the characters which we now find so troublesome. In the words of Norbert Wiener, we have still to learn "the human use of human beings".

Moving into a New Epoch

In these days we are moving rapidly from the age of experimental technology into a new epoch of automation. The transition is so rapid that we can see only the rate of change and cannot yet appreciate the lasting effects of this world-wide revolution. Just as a few generations ago the age of the cottage industry was drawing to a close, so now the age of the factory craftsman and the accounting clerk is reaching the evening of its days. We are in the habit of congratulating ourselves upon our inventiveness and enterprise, but we realise that almost as important are human indolence and fatigue. Furthermore, we are always biting off more than we can chew. The evolution of human society is not like a well-conducted military operation. We do not reconnoitre and plan our attack and consolidate the ground we win. While the battle is still raging around one objective, the rest of us are already galloping off to some new horizon. With millions of square miles of our own planet still unexplored and uncultivated, we are intently planning the capture of the Moon. While our children are still struggling in their solemn classrooms to unravel the mysteries of decimal arithmetic, vast computing engines are solving instantly problems few mathematicians could even define. Perhaps in the future, in some schools at least, children will be allowed to play the game of arithmetic if they choose, but will be taught very seriously the principles of binary computation and statistical topology.

Already it is worth considering whether mechanical aids to thinking must be limited to problems in

arithmetic and formal logic. Operations in these modes can certainly be mechanised more easily than others because it is easier to make a switch than it is to design a vacuum tube, but the possibility of amplifying our reasoning powers with artificial thinking machines should not be rejected out of hand.

I have already suggested that a great deal of our life is directed by hunches and intuitions rather than by formal logic. The review of brain activity I have outlined implies that a probabilistic way of thinking is in a sense a more fundamental, though less easily defined function, than the process of logical deduction. If this is so, once we have begun to understand how such mechanisms have evolved and how they are represented in our own brains it is an obvious step to incorporate them in domestic machinery. Many of our compatriots stake a proportion of their modest incomes on a few marks on paper which experts tell us could be determined by the toss of a penny. We are all gamblers at heart, but few are prepared to gamble consciously with more than a part of our resources. Most amateur gamblers are happier if they operate some system, even though statisticians assure them that such devices are childish superstitions.

What I am suggesting is that it may be possible to devise a mechanical system to gamble with the Universe; I may be the victim of the same prejudice and apprehension as the sparetime punter. The world may be unintelligible in these terms and we might do as well to get our winning lines in the traditional manner; if in the gamble of living we were always cool and patient, the portable computer in our heads would probably be as good as any we could make. But civilised man is the prey of so many cross-currents of appetite and fear that he may not keep his head long enough even to complete the table of his wager. Instruments to estimate as we do the pattern of favourable circumstances might not be more sensitive or more accurate than we, but the production engineers who would control their manufacture would surely see to it that they did not include in their design the fears and prejudices which deflect our judgment and threaten to destroy our Society.

REPORT AND DISCUSSION

Chairman: Sir WALTER PUCKEY, M.I.Prod.E., F.I.I.A.,
Past President of the Institution.

OPENING the meeting, the Chairman said that a Past President was sometimes called upon to deputise for the President, and he was very pleased indeed to do so on this occasion. He would also like to welcome the distinguished visitors, and also his old colleagues of the Institution, many of whom had done so much to bring the status of the Institution to its present level. He would also like to thank the University for providing such wonderful facilities and particularly to welcome Professor A. R. Collar, Head of the Department of Aeronautical Engineering, who was representing the University.

The Chairman continued:

"I think it is most appropriate that this Paper is being given in Bristol, and that it is linked with the name of Lord Nuffield. There is no industrialist who has done more for this country than Lord Nuffield. He holds a high place as a man, and as a Past President of this Institution who has devoted time and money not only to machines, but to men and women, and what more appropriate Paper could we select to honour his name?

"And now may I refer to our lecturer, Dr. Grey Walter. Until last year I knew him by repute and I had been fascinated by his book 'The Living Brain'. I hope he won't mind me saying that after reading his book I referred to him as Dr. 'Grey Matter' Walter. You will, when you hear him, come to the conclusion that there is nothing grey about him. Bristol knows and honours him as Director of Research at the Burden Neurological Institute. He was born in the United States and their loss is our gain, as you will see from the list of important jobs he has held. He is a co-founder and Editor of 'Electroencephalography and Clinical Neurophysiology', an author of various books and many Papers. He is a distinguished representative of his profession."

(Dr. Grey Walter then presented the Paper which appears on pages 4/12, demonstrating some of the working models to which he refers, and showing a number of slides to illustrate certain points.)

Mr. Stafford Beer, *Production Controller, Samuel Fox & Co. Ltd.*, opening the discussion, said he felt that to open this discussion was a great privilege, because it marked the official introduction of the new science of cybernetics to industrial engineering. In 10 years' time, those present would be saying with pride: "The Institution of Production Engineers took note of this 10 years ago".

New discoveries were often the result of the merging of thoughts taken from widely different fields, and in these days of high specialisation opportunities for this were all too few. Someone had displayed great imagination in bringing an eminent physiologist to the engineers that night; and they would have poor imaginations themselves if they had not been captured by so eloquent, though so erudite, an address. The question they must ask now was: was this to be more than just imagination? — were they going to do something about it?

The speaker had been too modest to suggest the industrial applications of his work; Mr. Beer did not feel this inhibition. Dr. Walter put them on the right path by saying that debate on the nature of "thinking" was barren. In industry, they had devoted themselves to the amplification of their physical strength, capacities for steadying and using precision and so on. This process of amplification had

Dr. Grey Walter demonstrates some of his working models.

stopped with thinking: with some people it was blasphemous to talk of a "thinking machine". But suppose they *could* extend the process by amplifying their ability to think. Dr. Ross Ashby had pointed out that if they could amplify a man's thinking power by the same ratio in which they had amplified his natural horsepower, he would have an intelligence quotient of one million.

In attempting this kind of progress, why should they use animal analogues at all? The answer was that the animal had spent millions of years evolving to cope with this earth's environments. In cybernetics, they could cash in on this natural selection. But they would not need to copy the brain in all its complexity, because in an industrial application they did not need to contain the huge variety and richness of human experience. It was a question of scale. Eddington, with his Cosmical Number, showed that the total number of electrons and protons in the universe was $\frac{3}{2}.136.2^{256}$. Dr. Grey Walter had told them that the human brain could enter into two-to-the-ten-thousand-million-squared states. It seemed that Protagoras was right: "man is the measure of all things".

So, if it was frightening to think of building a machine of this complexity, Mr. Beer thought that there was no need. They could meet their industrial needs with what the speaker would call a "model", or even a "toy". The key to the behaviour of this machine was the operation of randomising elements within what was called a Black Box. This cybernetic term meant a box of flexible connections, the internal states of which were unknown. A Black Box was capable of connecting 'n' inputs and one output in 2^{2n} different ways. He was thinking of a Box with merely eight inputs and one output. This simple device had 2^{28} possible states, which was 2^{256}; virtually Eddington's Cosmical Number. The ability of so small a machine to apprehend so vast a universe was both staggering and encouraging.

Applying similar thinking to the problems of production control in a steelworks, they knew how difficult it was to recognise representative situations. There were too many of them. The human brain happened to be particularly bad at this problem of observing patterns. He was now thinking of a machine with 40 binary elements — still a "toy". This would be capable of entering into 2^{40} single states: this meant they could use it to "label" over one million million situations. This was a small number on the cosmic scale: but in a works it should satisfy even the most lugubrious foreman. Would Dr. Grey Walter agree that they could handle an array of 40 elements, and could they not use it effectively in works' situations?

Mr. Beer said he would like to list some of the ways in which he thought they might apply cybernetic thinking industrially. First of all, and this required no machine to be built, he suggested that they should get used to thinking of any system they set out to examine as organic. Any system had a "life" of its own, and they could not treat these things in little bits. Mistakes had been made in production engineering, and particularly in work study, because of a failure to recognise that some part of a system, subjected to detailed study, was acting and inter-reacting in a complex way within a larger organic whole.

Secondly, it would be helpful to have intelligence amplifiers everywhere. A third possibility, most relevant in industry today, concerned computers. They knew that the journalists should never have called these machines "electronic brains": they were nothing like brains. It might take a man six months to do the brain-work attaching to half-an-hour's computing, and a "semantic machine" — which was a cybernetic device — was certainly required to translate the more complex algebras into holes and blanks for the computer to handle. Next came the machines for labelling situations and recognising patterns in them: these would be tremendously valuable in production control; so also would learning devices, such as they had seen tonight, which could amass experience. The scope was truly vast.

He thought, finally, that they needed cybernetic machines to control something which was in their minds as a trouble-

maker: he referred to automation. They knew that this was a juggernaut, a very difficult thing to control because it was completely insensitive to its surroundings and the pattern of events. Let them make it sensitive. If they could get something, at the moment fully determined, blind, to react to the circumstances in which it found itself, he thought they would have done something very great indeed.

Dr. Walter said with regard to amplifying intelligence, he was indeed trying to suggest that what was called intelligence could be amplified. He knew this would be useful in itself, but he also suggested that if a machine could be made to do this hard thinking, it would also enable individuals to free their own personalities.

The rules of logic which underlay thinking were common to everyone. But these rules were not the important thing about thinking; the ways in which people differed in their thinking were due to their feelings of the importance of things. He agreed that this led to the other point about the use of electronic computers in industry and research.

The recognition of pattern was again of obvious importance. Historians had all the information and they still did not know what caused the last War. It was certainly true that the human brain was not a good instrument for recognising patterns of this complexity.

Mr. L. G. Burnard, *Assistant to Superintendent, Vickers-Armstrongs (Aircraft) Ltd., South Marston,* said he would like to ask about unconscious thinking. They were all aware of the type of experience when they met someone in the street. They recognised the face and could not put a name to it. They became frustrated and could not think; the remembering seemed blocked and, then, all of a sudden, the name popped up.

They all had problems in their work; problems of design and administration for which they were called upon to find solutions. Sometimes they could not find one which was satisfactory by reference to their past experiences. They thereupon became a bit lazy and forgot about the problem for the time being. They said they would "sleep on it". It had been Mr. Burnard's experience many times that before very long, when it was least expected, a satisfactory solution seemed to appear in the conscious brain, just like the toast popped out of the automatic toaster when it was nicely done.

He thought that they were creatures whose brains stored somewhere all the experiences that ever happened to them. It was all there somewhere. Did they ever forget anything, or was it that they just could not remember?

At the reception preceding the lecture, the Chairman of the Western Section, Mr. W. U. Snell *(extreme left)*, **chats with Mr. F. C. Cooke, Vice-Chairman of the Institution's Papers Committee** *(extreme right)*, **and Mr. F. G. C. Sandiford, of the Western Section Committee** *(second from left)*.

Dr. Walter said that this was a very good example of conscious and unconscious thinking.

Mr. K. J. Hume, *Chief Education Officer, Dowty Group,* was impressed by the remarks on the great effort needed for logical thinking. They all knew of that difficulty when they had a problem to solve; they looked at it, they stewed over it, and it gradually sank in. Suddenly they got a wave of inspiration and it was solved. Was this process due to sub-conscious or automatic working of the brain? Did it start thinking by itself without conscious effort after a certain amount of priming?

Dr. Grey Walter referred to rhythmic signals, which were more rhythmic when people were relaxed than when they were thinking consciously. Mr. Hume could not help thinking of the television system, and he wondered if there was any vague analogy between them. Was there any significant correlation between that and thinking? A television signal consisted of regular sync pulses when there was a blank raster. As soon as a picture appeared, the waveform was of a more complex pattern superimposed on the regular pulses.

Were the brain pulses much different in sleep? Were they very much fainter, more regular, or was there no significant difference between pulses when people had their eyes closed and when they were unconscious?

Dr. Grey Walter had already said that individual characteristics could be determined by this type of oscillation. Seeing the similarity between pulse patterns of people closely related, working together, in love and so on, Mr. Hume wondered if it was by chance or was there some way in which close relationship could cause one mind to influence the functioning of the other brain?

In the not-too-distant future, they were told they might have a machine which would help solve some of our immense problems. This would be something like the ancient oracle but they hoped it would be a true oracle.

In reply to the first question, **Dr. Walter** said that there were five changes in sleep and it was possible to pick out moments of dreaming. It was a very long story, but very absorbing.

With regard to choice of partners, his own feeling was that if a lot of people were mixed together, they would tend to choose the first partners from people like themselves, if they were given free choice.

Dr. F. H. George, *Department of Psychology, University of Bristol,* commented that to say there are no mathematical tools, might create a wrong impression on the audience. There were a variety of mathematical tools in existence for the description of machine designs. For example, there was mathematical logic, Theory of Games, abstract algebra and probability theory, to mention some of the principal ones.

Secondly, he thought that the word "logic" was used in a narrow and misleading way. Logic should not be identified with deductive logic. There were more general forms of logic that could describe probability strategies and vagueness even.

As for the notion of a learning machine, Dr. George took it that this referred to machines that did not have all their abilities built in, but rather had built in the facilities for acquiring their own abilities. There was then some question about the application of these sort of designs in industry; he would have thought the possibilities for such designs in the industrial situation were, indeed, quite obvious.

His last criticism was of an early point in the Paper. It was said that one looks at wholes. In fact, this was only half the truth. As Lorenz had so ably said, they did not only look at the engine working to understand it; they would also, in general, take it to bits and study the parts. Both the wholes and the parts were essential to understanding complicated systems. He thought Dr. Grey Walter would probably agree with most of these points anyway.

Dr. Walter thought that people certainly tended to think that logic was the highest form of thinking. He was, of course, only using the word "logic" in a colloquial

sense, and certainly it could be thought of as a more general sort of process. In fact, if thinking was not discriminated from logic, surely there would be no need for the two different words. Why use the word "logic"? Why not say "think", if they were the same?

With regard to the mathematical methods, it might be that they were of value, although it had not seemed to him that Theory of Games, for example, had been as useful as the volume of work that had been written on it suggested. It all too often happened that one had to do one's own mathematics, or where none existed, one had to build the machines one wanted to study.

Mr. John Sargrove, *Technical Director, Automation Consultants & Associates*, said he was an engineer, not a neurologist. All the time he was listening to Dr. Grey Walter, his mind was working on the problem: "How can this new knowledge be used productively in industry?"

He thought the most important facet from the industrial angle was the ability to recognise automatically "complex patterns". To give one very important example: in a petroleum refinery, it was not possible, without elaborate testing, to obtain any idea of the stock of constituent liquid hydro-carbons in the crude oil. A new device that he could envisage could perhaps be developed able to recognise the "pattern distribution" of the various hydro-carbons such as hexane, heptane, octane, etc., within the crude oil being pumped out of the tanker ship, thus enabling an improved automation to be achieved. A complete knowledge of the true raw stock position before the refining was commenced could markedly contribute to the economies of programming the refinery.

Such variable quality crude oils occur with each shipment, for instance in the present Suez emergency, when crude oils from various totally different parts of the world enter one refinery, and could at present only be recognised by human intervention.

He thought that only when such more elaborate "pattern recognition" devices were used in industry would it be possible truly to automate an industry. The yes/no type of devices, which were the main tools today, were very handy but very limited. He suggested there was a very fruitful field in which engineers would be able to collaborate with Dr. Walter and other neurologists. One similar co-operative research which came to his mind was the conversion of the very complex pattern of human speech into coded electric pulses which require a very narrow band of frequencies, and their reconversion into speech at the receiving end of the communication channel. Here elaborate "pattern recognition" devices were evolved. This was a good example of the co-operation between people who were engineers and people who understood language. They had got to collaborate more closely to accelerate the field of development of such complex devices. He hoped that Dr. Grey Walter would think that was a worthy target.

Dr. Walter thought that with regard to complex patern recognition, this would take a long time. Sensing devices could become enormously elaborate. He certainly thought it was a subject worthy of study, which nobody had yet discussed in practical detail.

Mr. D. B Ebsworth, *Assistant Chief Inspector, Bristol Aero-Engines Ltd. (Rodney Works)*, said that as engineers in the mechanical sense, they had studied the mechanical movements of men and, as a result, had developed and used many mechanisms which relieved them from drudgery and discomfort when performing many mechanical tasks.

These mechanisms in many cases performed these tasks more rapidly and, indeed, more expertly than it was humanly possible to do, and their use often made it possible for one man to do the task of many, and in other cases they enhanced the skill of the craftsman.

To this end, it seemed to Mr. Ebsworth that the study of the human brain, and research into the means of reproducing its method of operation in thinking machines, and in changing or developing thinking machines from the binary stage to the cybernetic stage was important and a proper

Dr. Grey Walter *(left)* **with Sir Walter Puckey, who presided over the meeting.**

line of research. He felt that such development would ultimately relieve them of much of the tiring day-to-day tasks of statistical thinking and free them, if they were capable, to spend more time in logical thought.

Further, these machines should be capable of greater capacity of memory than man and, therefore, be less faulty in their statistical thought, being able to bring to bear a greater number of permutations of records than one human brain could possibly do.

Modern science often revealed truth in many old-world observations, and he was reminded of the comment that was often made about heroic types, in that they had "never grown up". It would seem from Dr. Grey Walter's rhythmic patterns that they did indeed not grow up, and the tendency for lack of control in early youth blossomed as a capacity for taking risk without calculation, which was often construed as heroism.

There was one small question which was raised in Mr. Ebsworth's mind by the comments on the effect on the Alpha-rhythm of sighted persons by the action of opening and closing their eyes. Was it the sense of touch in a blind man that replaced the sense of sight in a sighted man? Did giving a blind man something to touch have the same effect as opening the eyes of a sighted man?

Dr. Walter agreed that there was a certain type of individual who did not ever grow up, but remained juvenile for ever. It was evident from history that very few romantic adventurers were at the same time responsible, careful planners and leaders.

With regard to blindness, this was another story like sleep. Touch replaced sight. The most exciting feature of the brain was its extreme elasticity. If part of the brain was damaged or diseased, other parts of the brain took over. In blind people, the visual brain took over hearing.

The **Chairman** said he was afraid the time had come to close this meeting and as Chairman he supposed he should sum up. What had production engineers in particular learnt from this evening's discussions that they could put into effect?

As he looked back over the years he realised with great satisfaction how production engineers had increasingly turned their attention from machine design and control towards men and women who helped to produce the goods. Today, therefore, they found that the control of both machines and men was something which was accepted by the modern production engineer. How could they translate tonight's

knowledge into something that would enable them to control both men and machines better? He would not attempt to cover the whole field of application but would like particularly to emphasise the great importance that they attached today to education and training.

The Government had given a good lead in providing background facilities and it was now up to production engineers to do their job in educating and training more effectively the many people that industry required in future years. This was a many-sided job. It involved selecting people, training them and helping them to co-operate with others. It involved promoting people to higher positions and trying to provide means which would enable them to do a better job in better style.

Now, if they were to educate and train people better, they must devise a better series of tests in order to measure progress, and those in industry had devised many tests over the years. They had, for instance, devised a series of tests to measure mechanical aptitude and, at the other end of the scale, they had devised intelligence tests, which while useful, had tended to give negative rather than positive information.

It seemed to the Chairman, after listening to Dr. Grey Walter, that they now had the ability to think about a new set of tests, that is, those which not only carried the testing of engineers a stage further, but had the ability to test and to measure emotional reactions and possibilities. If they could use the research of the lecturer and his colleagues in this field alone, they would indeed have a new tool of great value; but there were other values that Dr. Grey Walter had underlined and, particularly to the Chairman, there was the great material and philosophical value of knowing himself better. He could think of no greater tribute to the lecturer or means of underlining the value of his lecture than by quoting the last paragraph of his book, "The Living Brain":

"The proper study of mankind, if we are creatures of purpose, has its proper application. Enough is known today about the living brain to reduce material waste and human misery — in education, in creation and in the development of mature personal relations. In an epoch of rapidly expanding human power, the application of the new and growing self-knowledge will concern not only the domestic or national future, but the destiny of the human species."

Mr. W. U. Snell, *Western Section Chairman*, who proposed the vote of thanks, said:

"I think we all feel that great changes are taking place in the world today — and if man can so order his behaviour by exercising a wisdom compatible with the knowledge and power now at his disposal, we can look forward to an exciting and attractive future.

"Now one begins to think about the position this country will occupy in the new order which we can see being formed around us — what peculiar contribution can we make which will ensure the continuance of the relatively high standard of material well-being to which we are accustomed?

"It is interesting to remember that at the end of the 18th century the population of Great Britain was about 10 million souls — the majority of whom existed at a level not greatly differing from that of the people occupying what we now call the undeveloped areas of the world. Our predecessors, however, by an astonishing display of energy and inventive genius, introduced and applied machinery which 'removed the drudgery from labour', and in the short space of 100 years raised this country to a peak of influence and prosperity, compared to the rest of the world, not likely to be achieved by any single nation again.

"Now in this country today there must be hardly a major undertaking which would not have benefited if more thought could have been given to it prior to actually starting work, and the more complex the project, the longer the time taken in correcting faults and mistakes in its conception. It seems to me we now need the aid of another device — to 'remove the drudgery from thinking', which will help to free our minds so that we can concentrate on those fundamentals on which we so often go astray. It is said: 'The hour brings forth the man'. If Dr. Grey Walter and his colleagues can help us to devise such aids, and so relieve the 'birth pains of progress', reducing wasteful expenditure of time, labour, power and materials, then they will indeed be 'men of the hour'.

"One of the most gratifying of a lecturer's experiences is to be received by a full house, which listens with rapt attention to what he has to say, and then falls over itself to participate in the discussion which follows. A sure guarantee that the lecture is regarded as important, and a testimonial to the lecturer as a recognised authority on the matter under review — all this, Sir, has been accorded to you this evening.

"It only remains for me to provide your audience with the opportunity to display our appreciation of the manner in which you have so ably expounded on such an absorbing subject. Gentlemen, may I, on your behalf, say, 'Thank you, Dr. Grey Walter'."

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development of trailerised bulk storage to line up to live storage operated by a line by line sequential controlling programme holds some extremely interesting possibilities.

So you see, not only have we installed everything on a live flow basis, but we have installed everything on a production sequential basis and have connected all the major processes by live storage systems, and we are now involved in installing a live storage system to material flow.

Now how about the overall control of this automated production outfit? You have been shown today, and you will have no doubt read one of the numerous articles which have been published, about our efforts in beginning to control sequential production in an organised way through the Hollerith system of punched cards. This first experiment of taking control of an industrial unit through some means by which an impulse can be sent when and where it is desired has shown up many interesting things. We have now a lot of experience, we know what to do and what not to do, and if any of you will be visiting us in a few years' time, we shall no doubt be able to show you some more very interesting things.

One more word or so, regarding the rate of automating the manufacturing processes themselves, in comparison with the automating of the material flow and the automating of the relationship between them and the sequential production. It is obvious that the automating of the material flow and the control of material issuing to the processes through a line by line time sequential programme is an immediate possibility, and can be carried out as soon as capital is available, and as soon as the human problem can be resolved. The automating of the manufacturing processes is another problem with many engineering and other difficulties, which will take quite a considerable period of time to resolve.

Midlands Region
Annual Conference

THE Annual Conference of the Midlands Region, which was held at the works of the Austin Motor Company on 16th May last, was attended by nearly 600 members and guests, and comprised the largest party ever received at Longbridge.

The principal members of the party were received by Sir Leonard Lord, K.B.E., Chairman of the Corporation and at that time President of the Institution. The morning was spent in touring the factory, and after luncheon the Conference assembled in the new Exhibition Hall, which has just been completed, to hear the three Papers which appear on the following pages. The subjects had been selected to complement the works visit in the morning, and this arrangement was most successful.

A short report of the Conference appeared in the July, 1956, issue of the Journal.

AN OUTLINE OF B.M.C. DEVELOPMENT IN THE FIELD OF AUTOMATION

by H. J. GRAVES,

Director, Austin Motor Company, Ltd.

DURING the next three-quarters of an hour we propose to try and give you a picture of our development in mechanisation of production since the end of the last War. Some people call this 'automation' but we prefer to look upon it as a natural development of mechanical means of increasing production. It has been going on in this factory for at least the last 20 years. It is not our intention to go into particular details, but to give you a broad picture of what has happened at Longbridge during this period. I propose to give you an outline of what we have done and my colleagues, Mr. Holbeche and Mr. Griffiths, who are speaking afterwards and have been more intimately concerned with the detail planning and design and manufacture of our transfer and unit machines and other automatic equipment, will give a more detailed picture of the problems we have had in this direction.

In 1939, before the War, Longbridge had reached a production of around 1,800 vehicles per week. During the War, of course, practically all our car production equipment was disarranged to make way for armament requirements.

When the War finished, we naturally had to put back the existing equipment which we had pre-War. At that time we had automatic machine tools but no transfer machines. Engine assembly was carried out on double strand chain floor conveyors, each individual engine being power brake tested, the finished material for assembly being located in bins and containers alongside the tracks. Gearboxes were built in a similar manner and axles were assembled on dead-line rail tracks. Dual duty conveyor with dead-line storage lines was in general use for the handling and storage of units and other material. Body shells were welded together in stationary jigs and the final painting of the body was carried out on bogies, pulled through a series of spray booths and ovens by means of a floor type chain conveyor.

One of our first steps after the War was to improve our engine, gearbox and axle method of assembly by marshalling all the parts which comprised the complete assembly, thus doing away with the bins and containers at the sides of the track, and passing them through washing machines before assembly: replacing all our power brake engine testing with running-in machines in which the engine was motored for 20 minutes without an oil base, oil being forced through under pressure to clean out the engine of any dirt or foreign matter.

Rising Production

By 1947 our production had risen to 2,700 vehicles per week, and in 1950 it had increased to over 3,000 per week and was rising rapidly. Our chassis assembly shop facilities were congested and plans were put in hand for a new finished car assembly shop. This was sited on what had previously been our Flying Field and was connected to the main works by an underground tunnel, 1,000 feet long, in which conveyors were installed for bringing the power units, axles and bodies to the new shop for final assembly. Automatic means were provided for transferring the unit from the delivery conveyors to the point at which they were required on the assembly tracks and new type floor conveyors were installed in the shop, giving a potential capacity of 8,000 vehicles per week, from four tracks. Marshalling of the components for assembly on the actual tracks was arranged as for engines and gearboxes and the stores for the delivery of finished components was sited around the marshalling area at one end of the shop. Simultaneously with these arrangements, plans were put in hand for the installation of two completely automatic rust-proofing plants for the body shell, in which the complete bodies were rotated through various cleaning, phosphating and priming operations before going to final colour painting. At the same time two new conveyorised paint plants were installed to deal with finish colour painting, to give a potential capacity of 45 painted bodies per hour, and special floor type conveyors installed for dealing with the trimming and finishing of the bodies.

In 1952 we had reached a production of 3,250 vehicles per week and the merger with Nuffield then took place. With this came a rationalisation of production and arrangements were made that all the power units for the popular models, both Nuffield and Austin, would be manufactured at Longbridge. This meant that we had to cater for a production of 6,000 engines and gearboxes per week, comprising 3,000 of each of two types, with the same machine shop factory area that we had prior to the War. We had also to accomplish this with very little addition to our labour force, due to the shortage of labour generally and, at the same time, increase our vehicle build to 4,000/5,000 per week. All these facilities have been planned on the basis of the factory working an 80-hour week.

We felt that there was little we could do to increase speeds and feeds and actual cutting times. With modern tungsten carbide cutting tools these, with perhaps a few exceptions, had reached their maximum. Analysis of a number of jobs often showed that the longest element of time was the handling and loading of components into and out of the fixture, often, as in the case of monoblocs, etc., with considerable fatigue to the operator. It was to reduce this work element that we decided to go in for transfer and rotary type special unit machines in which the component was loaded and unloaded into and out of the fixture whilst the machine was operating and, in the case of transfer machines, only once for some 20 or 30 operations.

Transfer and Rotary Indexing Machines

Since making this decision we have installed, and these are working in the Group, some 60 or more transfer machines and about 150 rotary indexing machines. Naturally, the capital outlay for these machines has run into millions of pounds, but we are satisfied that it has not cost us more to install transfer and unit machines than it would have done to have installed general purpose machine tools to do the same volume of production. At the same time, the transfer machines provide a means of mechanically moving the component from operation to operation, keeping the floor free from work and a saving in production labour. It has thus been possible to divert the labour which has been displaced to other machining work, to enable us to increase our production to present-day figures of 5,000 vehicles and 8,000 engines and gearboxes per week. As evidence of this, since we have introduced these machines our total number of employees has increased and without these machines it would not have been possible for us to have achieved these outputs.

At the outset we considered different designs of transfer machines, but we finally decided to adopt the unit principle of building up the machine from interchangeable bed sections, unit heads, columns, bed extensions, etc. This means that when a new model is introduced, or a change of design takes place, the only items which have to be scrapped and replaced are the multi-heads, jigs and fixtures, etc. The main machine can be broken up and its units rebuilt to form new machines, if required. It is also possible to insert additional operations into a machine which is already built by splitting it and adding new bed sections, etc. We have never regretted taking this step, as it has given us a degree of flexibility which was a feature we were most afraid of losing when we turned over to the use of transfer machines.

Efficient Material Movement

In addition to the machining side, we have also given a good deal of thought to the handling of material and assembly and new assembly tracks for the building of these same engines and gearboxes have been installed. Here again, we have adopted the marshalling method on the conveyor for the smaller components and conveyor feed from the stores to the tracks of major components such as crankshafts, electrical gear, flywheels, etc. This has enabled the components to be readily available for the operator and has, at the same time, eliminated stocks of material alongside the tracks.

Continual development in this direction will go on at Longbridge, and I think you will all agree that quite a lot can be done in most factories to reduce costs of material movement and reduce inventories by better material handling methods which can generally be achieved by simple means, with a fairly modest capital expenditure. Much has been said these last few years about the importance of efficient material handling, but I sometimes wonder if industry today is fully conscious of the savings that can be made by a proper consideration of material movement within the factory.

Only certain components such as monoblocs, cylinder heads, gearboxes, axle cases, etc., can be machined most suitably on transfer machines, provided always that the volume required is sufficient to justify the capital expenditure. A number of other parts can be more economically machined on rotary indexing type machines and we still have, and always will have, a large quantity of general purpose machine tools.

Automatic Handling and Loading

Future development will be to devise means of automatically handling the work between the machines and automatically loading the components into and out of both the rotary unit and the general purpose machines.

The Americans are perhaps some way ahead of us in automating their plants, mainly because of their large volume production, but a recent article in one of their journals stated that only 25% to 30% of the operations in American automobile plants could be automated at the present time.

There has been a lot of publicity, chiefly in the popular Press, in this country about "automation" but in my opinion this is being rather overdone.

Automation of our factories must be a gradual process for the following reasons :

1. the high capital cost involved ;
2. only large volume of production will justify the expenditure ;
3. these developments take considerable time to design and manufacture.

If we are to be competitive in world markets we must use automatic and mechanical means wherever possible — the overall results, if properly and intelligently applied, are lower costs, elimination of operator fatigue, greater safety, balanced and increased production, uniform and controlled quality and reduced stocks. It increases output per square foot of factory area and surely that is what we are all striving to attain.

DESIGN AND MANUFACTURING PROBLEMS

by H. W. HOLBECHE,

Chief Production Equipment Engineer,

Austin Motor Company, Limited.

DURING the six years we have been designing, building and using transfer machines and automatic equipment, there have naturally been many difficulties to overcome and problems to solve. In this Paper I propose to talk of some of the troubles experienced and the steps taken to overcome them.

It was stipulated by the management that with the introduction of automatic transfer machines, the traditional high quality of Austin products should be maintained and, if possible, improved. This, therefore, was the prime consideration at all stages of design and manufacture. The next requisite feature was absolute reliability. The importance of this will be appreciated if we remember that the transfer line is working to a fixed cycle, with no buffer stock between the operations on any one machine. Breakdown of machine or tools at one station will stop the whole machine and production so lost cannot easily be recovered.

Good design, discrimination in the choice of proprietary fittings and equipment, good workmanship, a well-organised maintenance routine, and systematic maintenance of the machine itself became of paramount importance, since generally speaking a car was lost every minute a machine was out of commission.

As was to be expected in a development of this magnitude, we had troubles of various kinds and about three-quarters of these were due to electrical faults. The quality of some of the electrical components was not quite good enough. Limit switches placed in exposed positions were a great source of trouble. Limit switches claimed by their makers to be water and oil proof, very seldom are so. In the open, on a transfer machine exposed to swarf, oil, moisture, dust and suds, their life is comparatively short. We now try to house all limit switches in water and dirt-proof cavities in the machine, operating them by plungers or levers from the outside. In our earlier machines, the entire electrical circuit worked on 400 volts A.C. This had the effect of causing heavy contact wear and helped to cause 'shorts' in wiring and breakdown of limit switches.

It was therefore decided, on our latest machines, to change over to 50 volts D.C. on the control circuits, still using 400 volts A.C. for the driving motors, combined with the most robust type of equipment procurable.

Magnetic Brakes

Another of our electrical teething troubles was magnetic brakes. These are fitted to the fast feed box of the unit head. Failure of magnetic brake, limit switch or operating contact causes the head to feed in to the work or fixture at fast feed. This was not entirely due to the type of brake, a contributory factor being the absence of a clutch between the motor and the fast feed unit. The brake was thus called upon to destroy the energy of the high revving rotor almost instantaneously. This problem has been solved by the fitting of a motor with an inbuilt clutch and brake mechanism, which was developed for us by one of the electric motor manufacturers. This has completely cured the trouble.

Hydraulics

As regards the hydraulic side of the machines, one of the lessons learned in the early days, was the necessity of maintaining scrupulous cleanliness of the oil. This may sound elementary, but its importance becomes much greater on long machines with many valves and cylinders. Dirt in the oil can cause scoring of cylinders and sticking valves. Care in the filling of the hydraulic system and the installation of magnetic filters has largely overcome this trouble.

On the long machines it is essential to have large diameter hydraulic mains without acute bend, in order to avoid excessive frictional losses and surge. Small diameter pipe causes increased velocity of the oil and consequent increased frictional losses. It also has the effect of increasing the time taken to operate the cylinders, especially at points remote from the pump.

This can be overcome by the use of a number of pumps spaced along the machine, which is expensive, or by the fitting of hydraulic accumulators ; we are using the latter method, with gas-filled accumulators.

The use of accumulators allows a small capacity pump to be used. The pump has time during the machining cycle to build up the pressure in the accumulators, which becomes available for instant use when required for unclamping, transfer and reclamping. The pressure in the accumulators is such that the cylinders can be operated without causing the pressure in the supply main to drop appreciably below that required to operate the cylinders.

These accumulators have speeded up the operation of the clamping cylinders to only one-fifth of the time taken, using a pump of the same capacity.

Since it is not possible to eliminate surge completely, the pipes must be firmly attached to the machine and separated from each other to avoid abrasion. Failure to observe this precaution caused us to have to replace the piping on some of the earlier machines.

Control of Swarf

One of the greatest difficulties on transfer machines is the control of swarf. As you will have seen, our machines are designed for the swarf to fall into the bed, which forms a trough running the whole length of the machine. It is carried along this trough by a scraper conveyor and deposited in a skip at the end. Unfortunately, much of the swarf remains on the fixture or platen, or is scattered over the machine. This causes trouble, because it may fall on to locating faces, preventing accurate location of the component or platen. Special guards have been designed and fitted to shield the location faces. As has been previously mentioned, it may fall on to limit switches if they are not carefully screened and cause irregular operation of the switches. On machines where the component is clamped upward, air jets are provided to clean the location faces prior to clamping. Incidentally, compressed air should not be used indiscriminately and care must be taken to control the flying swarf.

On machines cutting cast iron, an overhead suction system will remove much of the fine cast iron dust. The only known solution of the swarf problem is regular cleaning of the machine. We have portable industrial type vacuum cleaners which are a great help in doing this.

One of the first points to be decided when considering the original design of a transfer machine, is whether the machine shall be of the platen or non-platen type. This is largely governed by the shape and size of the component, and whether it has suitable faces for transfer and location, and whether it can be accurately located at the working stations. Such components as cylinder blocks and heads readily lend themselves to this and, for these and similar jobs, non-platen machines are preferred.

Greater accuracy in the component can be obtained by this method, because the pilot bushes for the tools can be carried in the rigid station fixture, which also carries the component locations. On the platen type, of course, the platen has to be accurately located and clamped at every station, with the pilot bushes usually carried in separate brackets. It will be appreciated that any wear in the platen locating plungers or bushes, or any swarf or dirt between the platen and its locating face, will be reflected in the accuracy of the job. These inaccuracies can in most cases be overcome by fitting floating bushplates, picking up fixed locations on the platen fixture.

Machining Awkward Shapes

Some jobs, however, cannot be handled on non-platen machines due to their awkward shapes.

You may have noticed that our induction manifolds are completely machined on one platen type machine. Exhaust manifolds are also dealt with on a platen type machine, with the exception of the spherical seat for the exhaust pipe connection, which unfortunately is completely inaccessible when the component is in a suitable position for all the other faces to be machined. We might here point out, that if it had been possible to machine this job on a non-platen machine, the component might have been indexed into a position for enabling the spherical seat to be machined.

Frequently, on platen machines, the fixture itself is a hindrance to the presentation of the tools to the work and governs the extent of the work that can be done on the component. One often finds that after the provisional planning of the operations which it is desired to perform on the machine, the path of the tool leaves no space for the fixture. Certain operations, therefore, have to be omitted from that machine.

You possibly remember, from your tour of the works, that three different methods of returning the platen are in use. On the early machines, travelling overhead electric hoists were installed, and some of these are still in use. The overhead track could not be placed over the centreline of the machine because

of the difficulty of avoiding vertical columns. They were, therefore, erected to run round the machine in a closed circuit, but this proved to be a great nuisance because of suds dripping over the gangways and the risk of injury to personnel. This method is being replaced by a turntable at both ends of the machine, each of which is connected to a power driven belt conveyor, by a short curved roller track.

Unfortunately, this method increases the floor area of the machine.

On the second batch of machines, this disadvantage was overcome by returning the platen on a conveyor running alongside the centre beds, through apertures in the branch beds. To do this, the platen is cross-indexed at the unload end and lowered by a hydraulic lift to the level of the conveyor. Another lift at the loading end raises it to machine level, where it is again automatically cross-indexed to the line of transfer. This platen return system is arranged to be automatic. To make the platen type machine completely automatic, that is, requiring no operators, presents many problems. The problems on the non-platen type are much simpler and our new machines are of this type, being automatically loaded and unloaded.

Reducing the Time Cycle

As production demands rose, attention was focussed on means of reducing the time cycle. We felt that reduction of cutting times by increasing feeds and speeds was undesirable, because it would entail more frequent tool changes, higher tool grinding costs and shorter tool life. Our policy is to run at medium feeds and speeds to obtain maximum tool life and minimum down time. This left only the non-productive part of the cycle where savings could be effected. The speeding up of the hydraulic clamping and transfer has already been mentioned. The speed of transfer was controlled by the necessity of avoiding overrun of the platens or component. It will be understood that if a platen overruns, the limit switches do not operate and the cycle stops. The original transfer method was by dogs on the transfer bar, engaging hinged pawls on the platens, or *vice versa*. We now positively locate the component or platen on the transfer bar, so that overrun cannot occur whatever the speed of transfer.

The regrinding and resetting of tools on transfer machines presents problems which do not arise on the conventional types of machine tools. Remembering that the operator cannot see the long line of tools along the machine, it is essential that they should be changed at regular intervals and well before there is any likelihood of the tool collapsing.

This safe tool life is determined by trial during the demonstration of the machine and a schedule prepared showing the times at which the tools at the various stations should be changed. They are not all changed together, but in groups, during meal times and shift changeovers.

In order to reduce this changeover time all tools must be available in the shop, reground and pre-set. At least three complete sets of tools and adjustable holders are provided, one set in use on the machine, one in regrinding and one in the special tool cabinets serving the machines, where pre-setting gauges are available.

The Problem of Drill Breakage

Regular tool changing will not entirely eliminate broken drills. It has been found that owing to peculiarities of a particular operation or condition, such as chilled castings or the drilling of deep holes, drill breakage may occur at these stations far more frequently than where conditions are normal. Broken drills may be detected in two ways, by probing the full depth of the hole at a succeeding station, or by checking with an electrical drill breakage detector developed at these works. This consists of a fixed coil mounted on the bush plate, surrounding the end of the drill in the retracted position. If the drill breaks, thereby leaving the coil without a core, the characteristics of the coil are changed and the machine stopped. The coil is embedded in hard plastic which is impervious to moisture, etc.

One of the problems now being studied is that of automatic gauging, which will be essential on fully automated lines. As a beginning, gauges are being installed on transfer machines to check the diameter of bored holes and to give warning when they are approaching the bottom limit. If the bottom limit is passed the machine will stop. There are a number of excellent gauges of this type on the market and there is no great difficulty in applying them in the way described. The cost has to be seriously considered, however; not only the cost of the gauges themselves, but of the additional stations which have to be built into the machines to accommodate them. The job becomes more involved when the attempt is made not merely to give a signal or stop the machine, but to arrange for the gauge to control the adjustments of the tools. The difficulties involved are not insurmountable and there is little doubt that much progress will be made in the next year or two. These remarks are intended to apply to transfer machines; control of size on grinding machines is already an accomplished fact.

Guarding of Transfer Machines

As regards the guarding of transfer machines to meet the requirements of the Factory Safety Acts, we must confess that the tendency until recently has been to ignore the matter. Guards of the conventional type would be exceedingly cumbersome, and on the more intricate machines almost impossible to apply without making the machine practically inaccessible for tool changing and maintenance. The numerous grids and screens would all have to be electrically interlocked so that the machine could not be used if any of the guards were left open or removed, and we know from experience that if guards can be left off, operators will leave them off.

For modern machines new conceptions of guarding are necessary.

One of our machines which you probably saw during your tour has therefore been fitted with photo-electric cell equipment, which provides two complete screens round the machine, one round the extreme perimeter and the inner one closer to the danger points. Breaking of the outer beam operates a hooter and illuminates a danger notice, thus giving warning that someone has entered the danger area. Breaking of the inner light ray stops the machine. The operator himself is unable to approach the tools without first switching the machine from 'auto' to 'inch' which puts the beam out of action. The same key which is used for this purpose has also to be used for turning a switch at the station requiring attention, before the inching button will operate. As only one key is provided, the operator or setter is free from the danger of someone else starting up the machine.

These points which I have briefly discussed are problems we have met in the development of transfer machines for machining operations.

The design of automatic assembly machines offers new and interesting prospects which are now being studied, and consideration of them must be left to a later date.

AN OUTLINE OF PROCESSES, ASSEMBLIES AND MATERIAL MOVEMENT

by F. GRIFFITHS,

Production Development Engineer,
British Motor Corporation.

WHEN talking about automation one must ponder a while to make sure what it is that we are really trying to describe. When we refer to the automatic factory, we are referring to a factory that is 100% automated. The 100% automatic factory is a complete dream, at any rate when viewed from conditions of today. On the other hand, if we refer to a mechanised factory, we only include that degree of automatic action which is a part of the division of labour skill. It seems to me that by using the term 'automation' we are describing all that which can be thought out and installed to operate between those two. It is on looking at this job of automating this very large in-between field that we can come to some very interesting ideas.

If you are not at the moment suffering from acute mental indigestion from the observations which you have made during your tour this morning, you may be able to correlate your observations to what I am going to talk about.

You will have noticed that we begin our production activities in basic manufacturing processes such as producing pressings, producing forgings, producing parts made from bar automatics and producing castings. Following this, you will have noticed those manufacturing processes involved in what we call 'machining', which shapes and finishes the components produced by the basic manufacturing processes. Moving along from these manufacturing processes, you saw the final process during which all the various components and units are assembled into power units, bodies or cars.

You will have noticed that complete mechanisation and a considerable amount of automation has taken place in the processes which we have in operation. In fact, an enormous amount of real work and achievement has been carried out in the automated co-ordination of these processes.

I will explain to you later how the very considerable engineering problems involved in automating the manufacturing processes need not in any way interfere with the automating of line by line programming.

You have heard from Mr. Holbeche about the engineering problems which he has had to deal with, and I now propose to talk to you about some of the things which we have done, and the principle behind them, regarding the more general engineering problems of automating the processes and also automating from the processes to the assembly.

When we started out to replan these works after the War we found ourselves in rather an undecisive position; our line flow of pre-War days had been largely thoroughly disorganised by the War demands. We purchased extra plant and rearranged the existing plant in the various machine shops so that we got a very significant increase of production.

It was during this relaying out of the various machine shops that the question of material flow and assembly came under discussion and assembly was

first reviewed. We made the decision that no longer were we going to place large masses of material alongside the assembly tracks, which not only was wasteful in labour time but made real production programming and material control extremely difficult. So the idea of material marshalling was born, first of all applied to engine assembly, in which every component, except nuts, bolts and washers, which we call 'chicken feed', was marshalled in a special Marshalling Stores placed alongside the beginning of the assembly tracks. From these Marshalling Stores were fed on to the assembly track complete sets of components for each jigged assembly station.

Importance of Material Handling

As you might expect from engineers who had been brought up almost entirely on the manufacturing processes, the actual business of moving and handling material was to place special mobile binning to operate between the manufacturing lines and the Marshalling Stores, and to operate between the Main Stores and the Marshalling Stores. This condition of manually moving stock along the processing lines, (except for a certain amount of roller track for such things as blocs and heads) and manually moving stock about the Main Stores and to the Marshalling Stores, was allowed to continue for a while, with the exception that when we prepared a new Body Painting and Finishing Shop and a new Car Assembly, it was found that the question of material flow and handling became of primary importance.

It is interesting to note that there are today no remains of our first efforts in material handling or in assembly, as our experiments and installation in our Body Finishing and Car Assembly Factories have forced us to install a close physical control of our stocks.

To revert to the results of our thinking and experiments during the initial planning of our present Body Finishing and Car Assembly Factories, you will have noticed that here we have built in quite a considerable degree of sequential process operational control and material flow. While we were engaged on the thinking and planning of the new and revised factories, the only material handling in operation was concerned with dead line storage of such things as power units and axles, and as for controlled sequential process operation, it was non-existent. All major processes such as Body Build, Body Paint, Body Finishing, Chassis Building and Final Assembly, Power Unit and Axle Production and Assembly were completely independent and worked as separate units.

This obviously could not continue and as you will have noticed, except for one break, the body has now an inescapable progression from the loose pressings to the finished car. It is interesting to note that this inescapable progression includes all strategic stocks to cover process, not shortage, breakdowns. This progression of the body to finished car is in these Works covered by a total time period of 24 working hours. Not only is the progression of the body inescapable, but all picking up and putting down operations are automated so that damage is controlled and at the same time sequencing normalised. Perhaps you engineers, seeing this as it now stands, and especially you younger ones, will think that it is all such a perfectly obvious thing to do, but it must be remembered that the step from production being under the control of almost watertight executives, to the position that they must produce to an overall line by line programme, and therefore, to the position that production must be by integrated team work and not by individual driving, was an extremely big step.

Now what has made this inescapable sequential progressive production possible? You will have realised that we are slowly working our way to quite a considerable degree of automation at Longbridge, and that this degree of automation will be in the sequential control of production by the inescapable sequential flow of material to, between and from processes, especially major processes.

This has been made possible by the introduction of the live storage conveyor, as distinct from the dead line storage conveyor of pre-War use and in use of most post-War factories today. There are of course, quite a large number of carousal conveyors being installed but these can be conceived as merely a rather weak effort to do somethings more than dead line storage. This live line storage conveyor is probably one of the most revolutionary pieces of production equipment of post-War activity.

As you will have noticed, the heavier type of live line storage is being used by us between all major processes of body production and between all unit assemblies and the final car assembly with quite a degree of sequential control.

Live Storage

How have we extended the use of the new principle of live storage at Longbridge and in other B.M.C. factories? You will have noticed that we live store all sorts of components of the larger type both in the machine shops, along the machine lines and from the end of the machine lines to the actual points of use in the assembly lines. We are also using live storage conveyors between our unloading decks and the point of use in our body build and body finishing tracks, and power unit tracks.

Now how about material flow? When we originally planned our Body Building and Finishing Factories and our Car Assembly factory, we were forced to face up to the condition of all material handling and flow which was in operation at that time, and while we were convinced that cheap light type conveyors were the correct medium of use in the factories, the organisation outside and within the factories was not capable of absorbing this new technique. We therefore developed probably the first complete container system ever to be put into an industrial unit. This system was carefully prepared and sold to the outside supplier and within the factories with quite astonishing results. Long before this universal container system was completely installed, we were developing what we wanted to work with the new live storage conveyors, and today you have seen the trailer bulk delivery and storage. The future

(*concluded on page* 16)

THE USE OF CARBON DIOXIDE IN THE ENGINEERING INDUSTRY

by T. B. PHILIP, B.Sc., A.R.C.S., M.I.Chem.E.,

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Abstracted from a Paper presented to the London Section of the Institution, 17th November, 1955.

MANY engineers already know something of the first tests carried out with carbon dioxide cooling and the progress made in developing an effective technique for general and specialised application in the engineering industry. It is very pleasing to have this opportunity to give a summary of the history and progress of the technique.

When carbon dioxide, in the form of liquid under pressure, is released to atmosphere it has the property of removing heat at phenomenal rates.

One of the fundamental principles of the method, now known as the CeDeCut technique, is the expansion of liquid CO_2 at such a temperature that 50% is changed to the solid form, giving a high concentration of the coolant in a restricted space. The solid form is finely divided and this CO_2 snow has the valuable property of adhering to metal surfaces, thus providing a reserve of coolant which will sublime when heat is applied. In practice, by the CeDeCut technique, expansion is done in such a way that approximately half the liquid forms finely divided CO_2 at a temperature of –100°F. and the remainder forms CO_2 gas at a similar temperature. The sublimation into gas of each pound of the solid so formed removes 250 B.T.U's of heat from the area on which it is projected. Each pound of liquid expanded in this way removes approximately 200 B.T.U's if it is assumed that the CO_2 gas leaves the system at atmospheric temperature.

Solid from Liquid CO_2

Fig. 1 illustrates the variation in the proportion of solid CO_2 formed by the expansion of the liquid at varying temperatures.

CO_2 Under Tool Tip

Fig. 2 shows a typical arrangement of a cutting

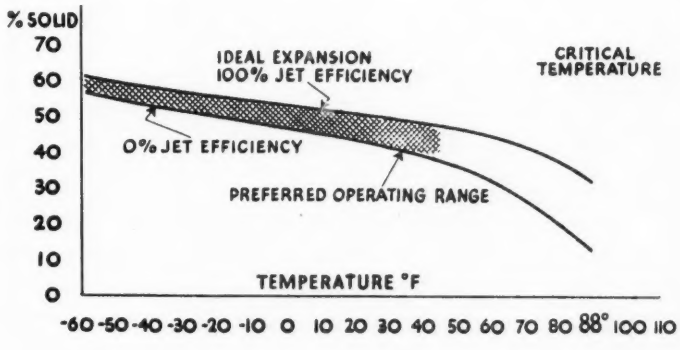


Fig. 1.

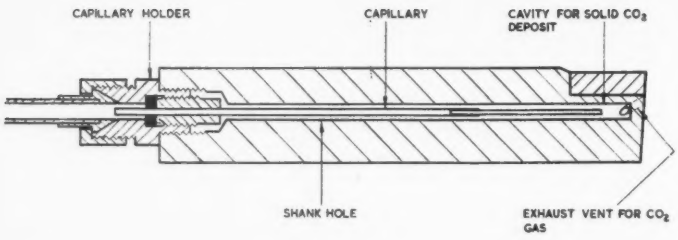


Fig. 2.

TYPICAL CARBIDE TIPPED LATHE TOOL
ADAPTED FOR USE WITH Ce DeCut TECHNIQUE.

tool where the liquid CO_2 is expended immediately beneath the tungsten carbide tip. The capillary tube controls the rate of flow of the CO_2 and the solid formed at the point of discharge provides a reservoir of coolant under the carbide tip. The small vent holes at the nose of the tool allow the gas, from sublimation of the solid carbon dioxide, to escape around the cutting edge of the tool and to discharge on to the workpiece to assist in maintaining it at normal temperature.

Tool Tip Temperature versus Time with Four Quantities of CO_2 and without CO_2

Tests have been carried out with a thermocouple mounted in a carbide tool and temperatures were measured with various flows of carbon dioxide at a constant speed in surface feet per minute with a constant depth of cut. Stable cutting temperature conditions were reached in the tool within a matter of seconds. With 2 lb. an hour of CO_2 expanded under the tool tip, the temperature stabilised at about 125°C.; with 4 lb. an hour the temperature dropped further and at 8 to 10 lb./hr. the tip temperature close to the cutting edge dropped below room temperature and stabilised at that temperature (Fig. 3).

Tool Tips with and without Carbon Dioxide

Fig. 4 shows the tips of Fischer tools after machining En 25 steel. The top one was cooled with CO_2 and has removed 3.2 times as much metal as the bottom one. It is interesting to note that the crater of the CO_2 cooled tool is smooth, whereas the other tool shows the usual signs of breakdown due to heat and chip welding with consequent removal of particles of carbide.

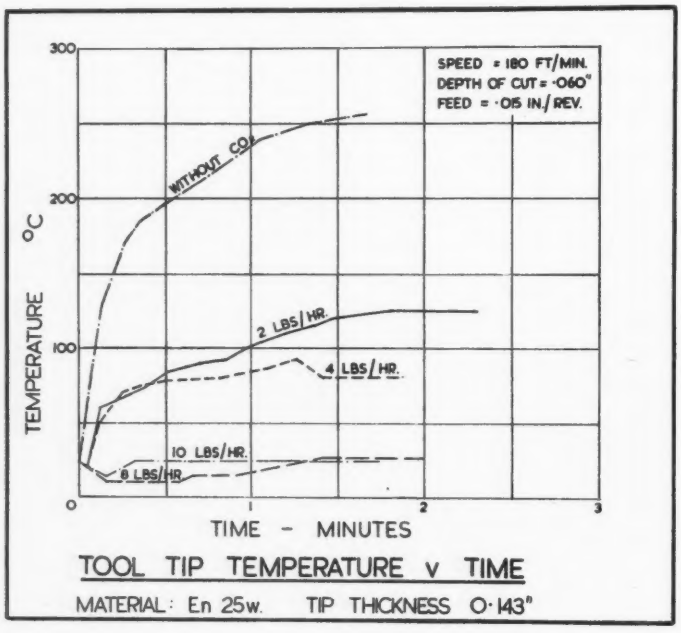
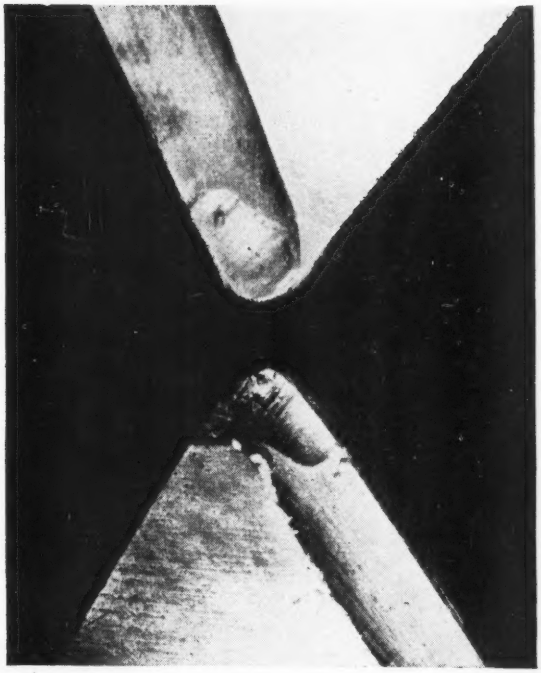


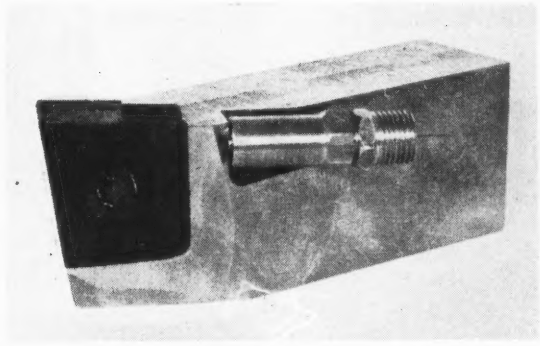
Fig. 3.

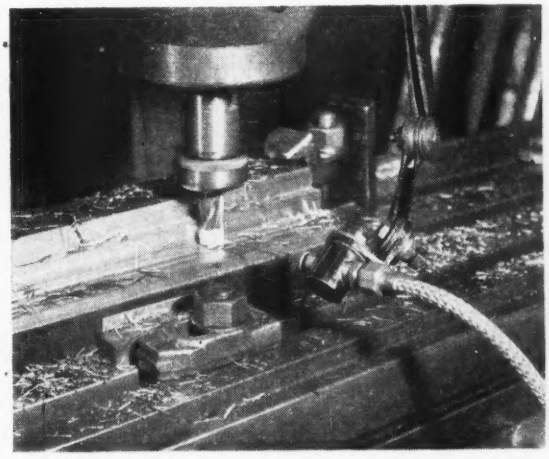
Fig. 4. *(top, right)*

Fig. 5. *(centre, right)*

Fig. 6. *(bottom, right)*







Insert Fischer Type Tools

Fig. 5 shows a special type of carbon dioxide cooled Fischer tool now being made in quantity.

The insert can be replaced in about 30 seconds without disturbing the setting, and a shank such as this, having the CO_2 capillary permanently fitted, enables tools fitted for CO_2 cooling to be changed more rapidly than conventional tools and reduces replacement costs.

End Milling Rex 448

The external application of CO_2 expanded directly on to the milling cutter is shown in Fig 6, with Rex 448 being milled at 350 surface feet per minute.

The carbon dioxide snow can be seen adhering to the metal keeping the cutter cold and the cutting edges clean, without the destructive pick-up of chip and dirt.

A great deal of the extensive field of grinding applications has yet to be covered, although a number of tests have been carried out and successful work is being done with the technique in grinding shops, toolrooms, assembly shops and test and research establishments.

The main observation is that by cooling the stock and the wheel at the same time, a very high standard of finish is given because the wheel is cold and clean and makes a continuous clean cut on stock that retains its quality and remains free from distortion because it is also kept cold while it is being ground.

An interesting example of finish is shown in the grinding of a typical carbide tipped tool with a coarse green grit wheel to give a finished surface of about $1\frac{1}{2}$ micro-inches. The carbide is protected against thermal cracking, the work is perfectly clean and the operator has complete visual and manual control.

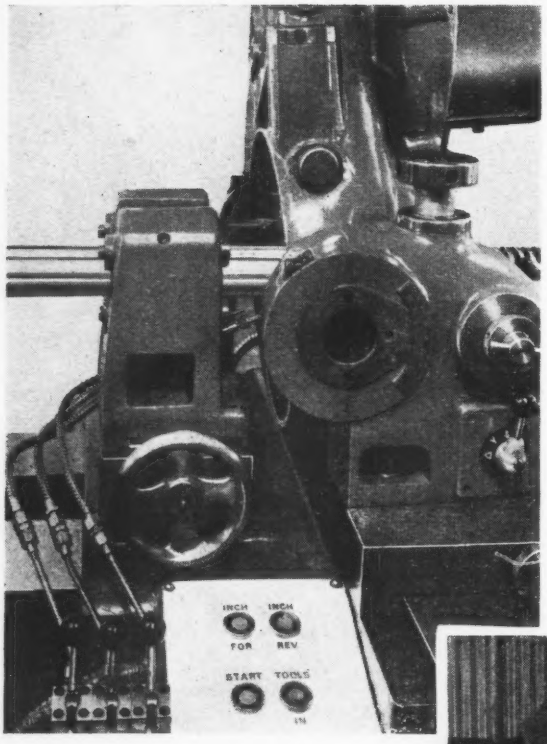


Fig. 7. *(above)*

Whirlmatic Thread Whirling Equipment

The interesting illustration in Fig. 7, shows the cutting head of the "Whirlmatic" machine of combined British and German manufacture that was exhibited at the Hanover Machine Tool Fair, and on which the CeDeCut technique has been particularly successful.

In this application, the cutters and the bar being threaded are cooled at the same time by a method specially designed for this machine to control workpiece temperature and increase tool life. By this method it is possible to achieve still better thread form and pitch accuracy with stabilisation of the bar because accurate tool life is prolonged, and the bar is under temperature control during the entire cutting operation.

The results are quite outstanding and illustrate the great value of effective temperature control on tools and material.

During development of the bulk storage and piped system with a special type of glandless pump to supply high pressure liquid CO_2 to large groups of machines, several types of cylinder equipment were produced for industry to make use of the technique until the equipment was available to supply whole production sections with piped-up liquid CO_2.

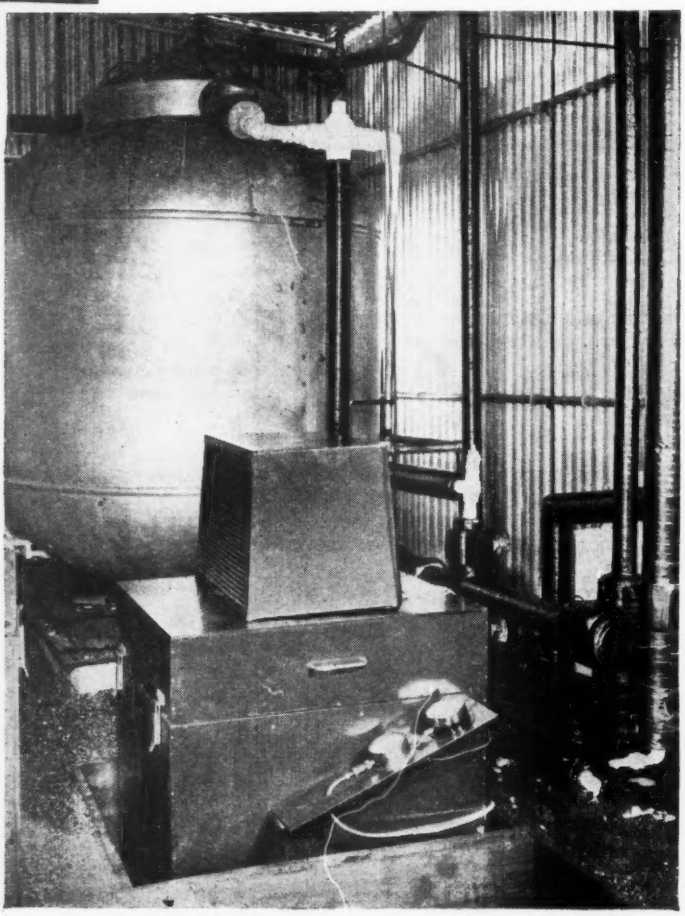


Fig. 8. *(right)*

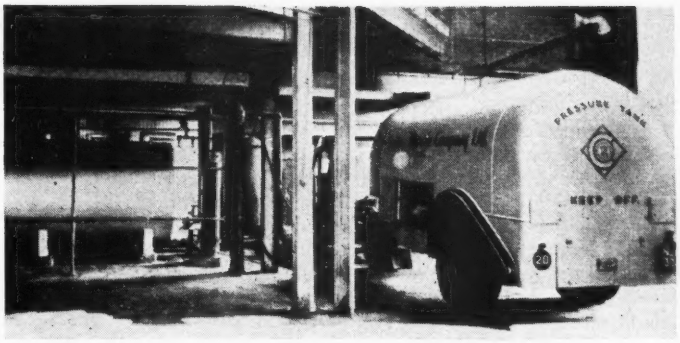


Fig. 9.

Bulk Storage Tank and Pump

A 1½ ton storage tank for CO_2 is shown in Fig. 8, with a glandless diaphragm pump which supplies liquid CO_2 through a ring main to each machine as required.

This is used in the test and demonstration workshop, but the capacity of the small diaphragm pump is sufficient to supply an installation of typical machines totalling about 1,000 h.p.

Large CO_2 Tank and Road Tanker

A larger tank of five to six tons is shown in Fig. 9, with the road tanker from which it is refilled. Pumping from the tank to the ring main continues while the tank is being refilled and there is no interruption to work in the machine shop.

Ring Main and Piping to Machines

A small part of the test workshop is shown in Fig. 10, showing the liquid CO_2 supply pipe coming down from the ring main to bring liquid CO_2 to cool the cutting tool in the H.E.B. lathe in the foreground. There is a warning system which operates should the proper working pressure of 900 to 1,000 p.s.i. fall below that level.

The ease and convenience of this system is an important feature, also the exceptional cleanliness of the workshop and machines.

Mark VII Mobile Unit

Fig. 11 shows the standard Mark VII CeDeCut Mobile Unit, developed for use as a general purpose equipment for works of all kinds where varied items

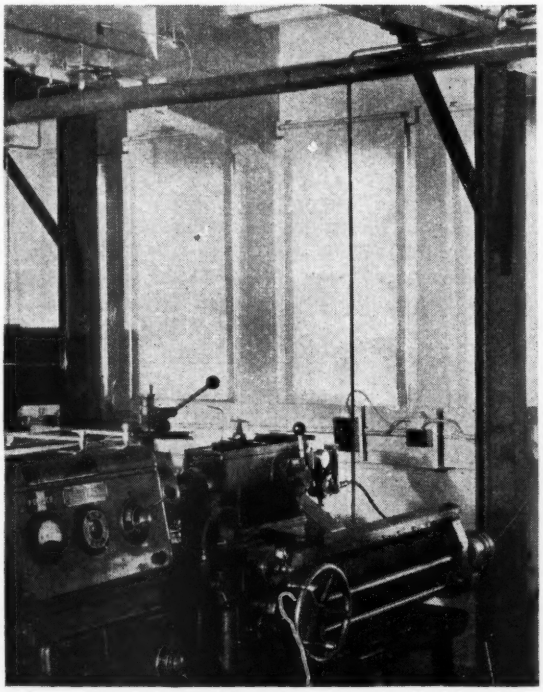


Fig. 10.

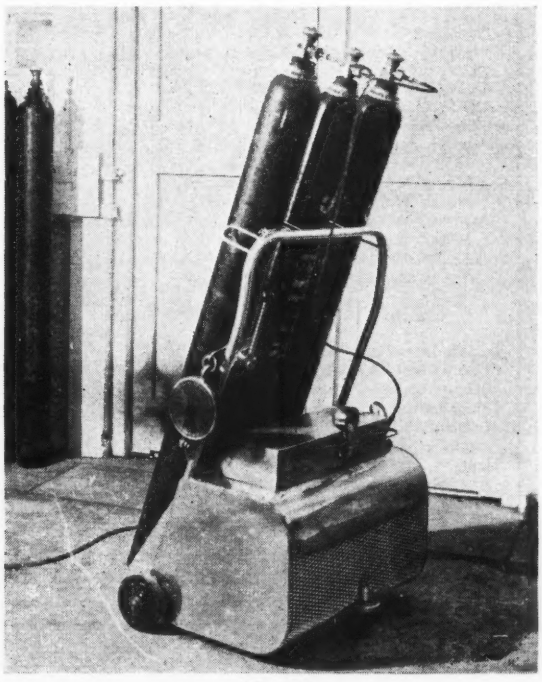


Fig. 11.

of short batch production require quick and easy transfer of the CeDeCut Unit from one machine to another.

In considering cost and production figures with the CeDeCut technique, it will certainly be appreciated by members of the Institution of Production Engineers that even a slight increase in the rate of production represents a large economic advantage, and in summarising costs and advantages gained by this technique a number of actual production examples are quoted. In these examples the names are not disclosed of the firms and departments who have made this production information available, and to respect their confidence details of materials and components are also restricted.

One very interesting factor is that in a range of analyses for various items of production, the savings are in much the same proportion.

Analysis of the Savings to be expected when Employing the CeDeCut Technique

The analysis is based on the following assumptions :

The number of hours worked per single shift year, assuming 44 hours per week, for 50 weeks is 2,200. Similarly, double shift working at 80 hours per week for 50 weeks would give a nominal year of 4,000 hours. Assuming 75% utilisation of labour, we arrive at a working year of 1,650 hours for single shift working and 3,000 hours for double shift working; "x" shillings represents the overall labour cost plus overheads based on 75% utilisation. For the purpose of simplicity in the present case, "overheads" are assumed to include all annual charges derived from cost of capital investment, supervision inspection and provision of works services.

Machine lost power is the power absorbed in machine gears and ancillaries. The shorter the machining time, the smaller the cost of this wasted power.

The price of CO_2 has been taken as 6d.* per lb. supplied at the machine from a bulk storage system and assuming that such a system is supplying only ten typical machines (it can well supply 100). The annual charges based on capital cost and on running cost have been included in the price of CO_2 at the machines.

The cost per tool regrind has been taken as 5/-.

* 6d. per lb. is taken as the actual cost of the liquid CO_2 at the machine, including the cost of pumping the CO_2 and providing a margin for losses.

Output and Cost Analysis—Machining with and without CO_2 cooling

Machine	Approx. cost installed:	£4000	
Previous cutting dry or liquid coolant:		Dry	
Floor-to-floor time:	Per component	43.5	mins.
CeDeCut floor-to-floor time:	Per component	22	mins.
CO_2 rate during cutting lbs/hr.		7	
CO_2 used	Per component	2	lb.
Assume single shift 2200 hrs. p. a. at 75% utilisation			
1650 hours p. a. on machine			
No. of components p.a. without CO_2		2275	
No. of components p.a. with CO_2		4550	
Assume double shift 4000 hrs. p.a. at 75% utilisation			
3000 hrs. p.a. on machine			
No. of components p.a. without CO_2		4136	
No. of components p.a. with CO_2		8272	

	SINGLE SHIFT		DOUBLE SHIFT	
	Dry	CO_2	Dry	CO_2
Components p.a. 1650 hrs.	2275	4550	–	–
Components p.a. 3000 hrs.	–	–	4136	8272
Labour costs per component @ ×/-	0.725×/-	0.366×/-	0.725×/-	0.366×/-
Machine lost power 5 h.p. @ 1½ per h.p. hr.	-5½d.	-2¾d.	-/5½d.	-/2¾d.
Coolant CO_2 @ 6d/lb. (actual cost at the machine including pumping and providing a margin for losses)	–	1/-	–	1/-
Annual charge based on capital cost of bulk supply 15% = £75 per machine.	–	-/4d.	–	-/2d.
Tool cost @ 5/- per regrind	1/3	3d.	1/3	3d.
Cost per component	1/8½+0.725×/-	1/9¾+0.366×/-	1/8½+0.725×/-	1/6¾+0.366×/-

Output and Cost Analysis—Machining with and without CO_2 Cooling.

Machine: Component: Material:

Saving per Component (single shift) ... ... = 0.359× — 0.1¼ on 4550
Saving per day (on 4550) ... ... = 5.94× — 1/8½ per day
Saving per annum (on 4550) ... ... = 1633.5× — £23.14.0d. per annum.
Saving per Component (double shift) ... ... = 0.1¾ + 0.359× on 8272
Saving per day (on 8272) ... ... = 4.4½ + 10.79× per day
Saving per annum (on 8272) ... ... = £60. 6. 0d. + 2969.6× per annum

Specific examples are as follows:

			Single Shift			Double Shift		
			£	s.	d.	£	s.	d.
Savings per component	× =	10/-		3.	5¼.		3.	8¾.
	× =	20/-		7.	0¾.		7.	3¾.
Savings per day	× =	10/-	2.	17.	8¼.	5.	12.	3½.
	× =	20/-	5.	17.	1d.	11.	0.	2.
Savings per annum	× =	10/-	793.	1.	0d.	1,545.	2.	0d.
	× =	20/-	1609.	16.	0d.,	3,029.	18.	0d.

These figures are impressive, but if industry is to gain the full benefits from this technique good machines with power, speed and rigidity are required —and equally important, staffs with the energy and outlook to encourage progress.

A great deal has gone into the development of this means to increase British engineering production and reduce costs. In many cases good use has been made of this technique; in others, there is perhaps a lack of enterprise and imagination in some of the industries for whose benefit the research and development has been carried out.

It would be appropriate to refer here to the extraordinary increase in the uses of CO_2 in the engineering industry. There have been many developments in other countries, particularly the U.S.A. and Russia, and improvements have been made to these techniques in this country, particularly in regard to the best methods and equipment for machining with the aid of liquid CO_2. In the last couple of years there has been a very substantial use of CO_2 in the new techniques for core hardening. Increasing quantities are required for the foundry industry, and appreciable advance has been made in developments in this country for its use in weld shrouding to replace the more expensive gases.

Carbon dioxide is also supplied as a solid in block form and is used for many purposes. It is of particular interest to the engineering industry when used with methanol baths for shrink fitting, but the CeDeCut jet is more versatile and is a most useful means of shrink fitting for dismantling and assembly work of all kinds and for control of temperature in various materials.

The time is coming, without question, when more and more factories will be piped up with liquid CO_2 to be drawn off where it can most usefully be employed for machining operations, shrink fitting and surface chilling of metals, temperature control with gas supply taken from the same central source for foundry and welding applications and other uses at present under development.

It is not suggested that CO_2 has a place in every operation and process, but there is a wise and profitable field for its use on fully established operations which it does very well indeed—and other valuable uses are being found for it by those who are ready to learn more about it and put it to work for their benefit.

Acknowledgments

Acknowledgment is made by the Author and the Institution to the Directors of the Distillers Company Limited for permission to publish this work.

The Directorate of Aircraft Production Development has been actively concerned in the machinability investigations.

THE PRACTICE AND PRINCIPLES OF TUBE MANIPULATION

A Thesis by T. H. WILKES, A.M.I.Prod.E.

THE principles and methods referred to in this Thesis are those which are being employed in the production of bent pipes and assemblies in such industries as aircraft, light engineering, and motor car production. It can also be applied to many other industries, having been used to great advantage in the production of preformed plumbing sets for prefabricated dwellings in the building industry.

An account of the methods used in the production of solid drawn tube is given at the commencement as an introduction to the subject of tube manipulation which follows.

The headings of the sections dealing with this subject are as follows :-

1. the production of seamless brass and copper tubes;
2. design and layout of bent pipe assemblies;
3. functions of production;
4. unfilled machine bending;
5. mandrel bending;
6. filled bending;
7. production planning;
8. production control;
9. costing.

1. The Production of Seamless Copper and Brass Tubes

The first stage of production is the preparation of the basic materials, which are then melted down and cast in the form of cylindrical billets, about 6″ - 12″ in diameter and about 4′ - 6′ long. This consists of process scrap and virgin metal, the proportions of which are specified by the laboratory, and carefully checked during manufacture to ensure that the requirements of the specification are satisfied. The tubes may be formed either by extrusion on a press, or by drawing through dies and over plugs on a drawbench. In the case of extrusion, the billets are sawn into lengths of approximately 8″ - 15″ long, which are now called blooms. The blooms are heated in a suitable furnace situated close to the extrusion press, which may be something in the region of 1,500 tons capacity. The bloom is placed in position on the press by a mechanical conveyor and the action performed by the press is as follows :-

A hole is first pierced through the middle of the bloom by the end of the ram, which is specially reduced in size for this purpose. This reduced portion is long enough to extend the full length of the bloom before the main part of the ram (which is nearly equal to the bloom in diameter) comes in contact with the bloom by means of a pressure plate, and forces it through a die (Fig. 1). The die determines the outside diameter and the punch of the ram and inside diameter of the tube so formed.

In the case of solid drawn tubes, the full length billet is heated and a hole pierced through the middle in a rotary piercing machine (Fig. 2), in which the billets are forced over a bullet nose plug by means of two barrel-shaped rolls set at a skew angle to each other. The plug is held in position by a mandrel of smaller diameter than the plug, to allow clearance

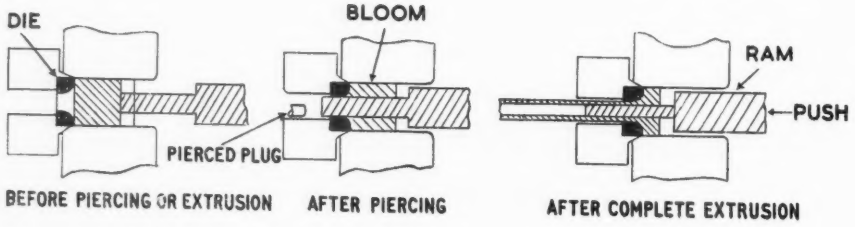


FIG. 1

for the pierced billet as it is propelled from left to right by the rolls. The mandrel in turn is firmly supported against a back stop.

The hollow shell so formed is now drawn through dies by means of a dog fixed to a chain conveyor built into the drawbench. The inside diameter of the tube is formed by a plug held in position by a rod. The shell or tube is first slightly reduced on the end so that it can be inserted through the die, after which it is loaded on to the plug. The rod holding the plug is then secured in position, and, at the same time, correctly located in relation to the die. The portion of the tube which is already protruding through the die is now attached to the "dog" on the drawbench. The grip is self-imposed by the load required to pull the tube through the dies. This process is then repeated the required number of times, using various dies and plugs until the desired size is produced. The cold drawing of the metal in this manner results in a considerable increase in the hardness, and it is therefore necessary to carry out an annealing or softening operation in between each operation to restore ductility. This is followed by pickling in acid in order to remove any scale so formed. Before despatch to the customer, the tube will be hydraulically pressure-tested to the required test pressure, and may also be heat treated to impart the necessary physical properties required.

2. Design and Layout of Bent Pipe Assemblies

The shape of a pipe may be determined either on the drawing board, resulting in a fully dimensioned drawing, or by the creation of a master pipe found from a trial run on the job. Whichever the method adopted, the shape of the pipe and size of bends so produced, will, to a large extent, determine the method of production to be adopted. The exercise of the greatest care at this stage will be more than well rewarded by ease of production and economical manufacturing costs.

The guiding principles to be borne in mind are :-

(a) the provision of bends of true curvature;

(b) allowing ample straight portions of not less than approximately 2" in between the bends;

(c) specifying bending radii which may be produced with the minimum of trouble. In general, and with certain limitations, these should be as large as is practically possible.

The subject of bend radii for light gauge tubes is a complex one. The following formula devised by the Author for 20 swg. tubes can be used as a very sound guide for most practical purposes and with most metals where bends are produced with accurate tools on suitable bending machines : RR = $D^2/3$ G; the root (or inside) radius of bend being equal to the outside diameter of the tube squared, divided by three times the wall thickness of the tube. Bends having these radii can be produced without resorting to filling. While not being unduly large they will have minimum distortion and be suitable for aircraft purposes. Where necessary, however, bends of a much smaller radii can be produced by filling the tubes.

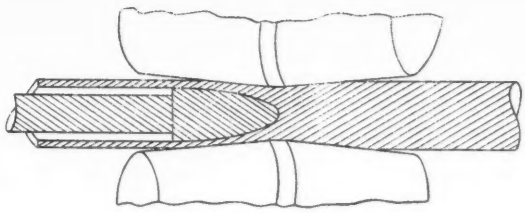


FIG. 2

This may be done with one of several fillers, or by a special bending machine fitted with a mandrel for supporting the tube during the bending operation. By using the mandrel method, machine bends can be produced approximately five times smaller than in the above method or RR = $D^2./.$ 15 G. With special equipment, bends of even smaller radii than this can be produced, but these, however, take considerably longer. Similar results can be obtained by the use of fillers which solidify in the tube, although the comparative time required for a method of this sort is very much greater, and the tube may require dressing to remove wrinkles which may form.

3. Functions of Production

There is a choice of methods from which to select the particular one to suit individual requirements. The choice will depend on the consideration of the following points :-

1. total quantity required with progressive deliveries;
2. standard of dimensional accuracy required;
3. design of pipe, whether simple, moderately difficult, or complex.

If the quantity is large, and the shape simple or only moderately difficult, these may be produced either in a press by means of suitable punch and dies or, as is more generally the case, on production bending machines. The production of dies for this application is usually an expensive business, and these will only be of value for any one particular item. On the other hand, a production bending machine, while undoubtedly having a higher initial cost, is capable of producing an unlimited number of different items using mainly standard equipment.

There are several different types of machines available, and the choice will depend both on the quantities involved and the standard of dimensional accuracy required. These machines vary from simple hand benders, costing a few pounds, to precision semi-automatic machines running into thousands.

If the pipe is of a complex shape it may be advisable to design and produce special tools or machines specifically for the purpose, or a standard machine may be utilised by making adaptation and using special bending tools. This of course would only be warranted where large quantities are required.

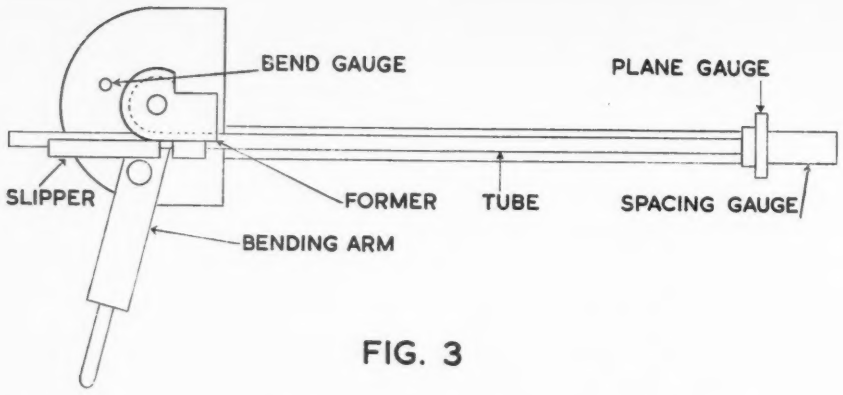


FIG. 3

A case in point is the production of cycle handlebars. Whilst a basically standard machine may be used, it would be so adapted and tooled that it virtually became a special purpose machine suitable for that particular job only.

In the case of small quantities, these may be dealt with in a variety of ways, again, depending on the complexity of the pipe, and the standard of finish and dimensional accuracy required. A pipe of simple shape, having bending radii of favourable ratio to tube diameter and gauge, could be dealt with by the use of standard bending machines and equipment by any one reasonably proficient in this type of work. On the other hand, with conditions contrasting in an opposite direction, a machine would be of little assistance, due mainly to the expense of providing special tools and the time necessary for adjusting and setting up. Pipes of this nature could be produced by skilled coppersmiths with no special tooling or formers, other than those usual to their particular type of trade. The production methods adopted would vary according to the quantities involved and the rate of delivery at which they are required. Where the quantities involved constitute a production run of suitably designed pipes, production would commence with the issue of either a drawing or a master pipe to the shops, and from this a checking gauge is made. This would be made of a suitable combination of hardwood and Jabroc, and so constructed as to form an accurate profile shape of the form required. The base of the jig would be constructed from good quality ply, of ample thickness, and suitably reinforced to prevent distortion taking place. If large quantities and a long production run are anticipated, with resulting heavy wear on the jig, it may be advisable to construct this of metal.

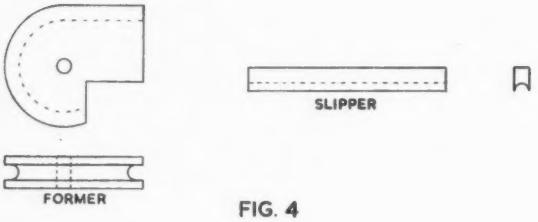


FIG. 4

If the shape of the pipe is not difficult and the standard of accuracy required not too exacting, the developed length of the pipe may be determined and all pieces cut to finished size before bending. Some variation however, will occur, particularly in regard to the overall length. With aircraft pipes and such like, however, manufacturers now insist that a working tolerance of $\pm$ .010" similar to that applied to machined components is maintained. In this case, an allowance must be added to the overall length of the pipe to allow for a final trimming to length operation after bending.

The length having been determined, the next stage is to determine on a bending machine the various setting positions for each bend, both in relation to one another, and to one end of the pipe. The exact method used will depend upon the type of machine used, whether for instance this is nothing more than a simple bending head, or one equipped with setting and indexing features for reproduction. Fig. 3 shows a sketch of a suitable machine, designed by the Author and manufactured specifically for dealing with repetition bending for accurate reproduction of bent pipes. In the former case the pipe will require to be "reset up" each time, (with specially provided equipment); in the latter the data can be logged for future reference. There are, of course, machines with varying degrees of facilities lying between these two extremes with the further possibility, where very large quantities are concerned, of special purpose tools or machine attachments of a permanent type.

Batches of work will now be issued to the shops, in cut lengths. The setting position for the first bend will be located, and this bend will be made in each pipe of the batch. The machine will then be changed for the second bend, and this will be carried out again on each pipe of the batch. This procedure will continue until all bends in the batch are completed. It may be necessary to carry out further alterations to the machine between bends, due to bends of different radii being present in the same pipe. It is obviously

advantageous to use bends of standard radii in the same pipe wherever possible. If the pipe is being produced to aircraft and similar requirements, it will be necessary to carry out some hand adjustments in between bends to overcome variations caused by differences of temper in the material and possible variations caused by machines or tools, again, depending on the grade used.

If the pipe has not been cut to finished length, a scarfing operation on one or both ends will now be required in order to finish it to exact length. This would be carried out either in a cutting-off machine, or by hand using hardened half-blocks as a guide, depending on quantities involved.

Where necessary, flaring operations would now be carried out for the pipes to accept AGS pipe couplings. Other pipes may require nipples, nuts, and banjos to be attached to the pipes by either brazing, soldering or welding. Where banjos or flanged type fittings are required, however, it would be necessary to provide a suitable jig in order to locate the faces and holes centre correctly during the process. Due allowance must be made for expansion and contraction of the assembly in the tool. It simplifies matters considerably if either of these operations can be carried out on one end of the pipe before bending.

It is not usually necessary to carry out annealing on the tubing before bending, as the material is normally supplied in a suitable condition. In special circumstances, however, heat treatment may be necessary in order either to anneal before bending, stress relieve after bending, or to impart special properties to the material to bring it to specification. In all cases other than those of light alloys, this operation would have to be followed by a descaling operation, where the presence of scale could not be tolerated.

The treatment is best carried out in a temperature controlled furnace, due reference being made to the maker's instructions. Where the quantities are small, this may be done with the use of a blow lamp, in which case extreme care is necessary to see that the material is not made too hot.

Descaling after heat treatment may be carried out by either pickling in suitable acid, or by shot or aqua-blasting.

The pipes, or pipe assemblies as they may now be, would then proceed through the normal finishing operations such as attaching of part number plate by either soft solder or silver soldering, pressure testing, painting or other finishing process.

One of the final operations would be a cleaning operation in the bore of the pipes, carried out by first flowing pure warm trichlorethylene through the pipe, followed by a tight fitting pull-through, and finally by blowing through the pipes with clean dry compressed air. The ends of the pipes would then be sealed to avoid the ingress of foreign matter during storage or transit.

4. Unfilled Machine Bending

This is the quickest and easiest method of bending and is adopted wherever possible. Fig. 4 shows a typical former and slipper such as is used for light gauge tubes. It has an accurately machined groove extending for an angle of 200° on a given radius, together with a straight portion, which may be used for clamping the tube. The diameter of the groove should be such that the tube will be a push fit in it. The depth of the groove should be about three-quarters of the tube diameter. This will ensure that the tube has the maximum support against distortion during bending.

The pressure for bending is applied through the medium of the slipper, which is grooved to the tube diameter, and is a push fit inside the former. The tube is inserted in the former (Fig. 3) with one end located in the spacing and plane gauge. The slipper is inserted between the tube and bending roller and the roller adjusted by means of an adjusting screw to give the required bending pressure. For normal purposes this will be achieved by allowing a clearance of 1/16" between roller and slipper in the neutral position. The bending arm rotates on the same axis as the spindle locating the former, through an angle of not less than 200°. By this means bends of 180° or return bends can be made. The bend is made by rotating the bending arm through the required angle, the amount of travel being accurately controlled by the bending gauge. The former and tube are firmly secured throughout the bending operation by means of a quick-acting toggle clamp.

5. Mandrel Bending

Tubes which, by virtue of the small ratio of the bending radius to tube diameter and wall thickness, require support during bending, to prevent either

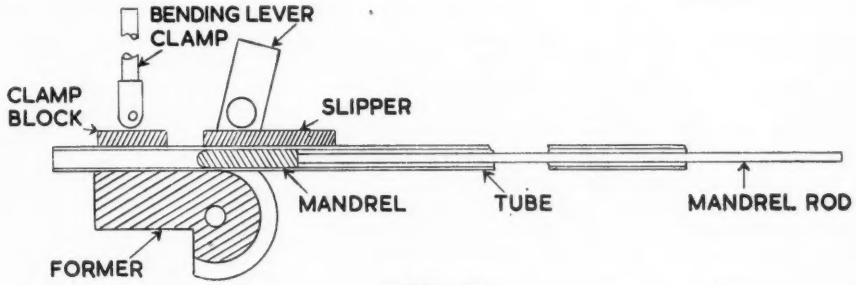


FIG. 5

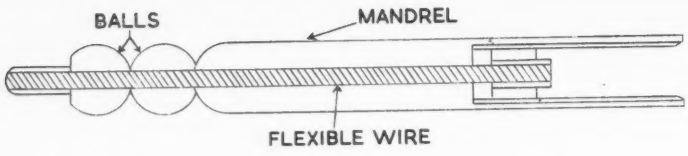


FIG. 6

acute distortion, wrinkling of the inside, or complete collapse, may be loaded with a variety of fillers, or, in all but exceptional cases, supported mechanically by means of a mandrel bending attachment. Fig. 5 shows a typical set-up with mandrel in position for this operation. With the exception of the mandrel, the same tools are used as for unfilled bending. The action, however, is reversed in this instance and is as follows :-

The bending arm now remains stationary, or is replaced by special adjustable support rollers, which take the bending reaction through the medium of the slipper. The tube is clamped to the former by suitable means and rotates about its axis to the predetermined angle of bend. The mandrel is located inside the tube in such a way that the tangent of the radius on the leading edge is between approximately 0″ to 1/8″ further forward than the centre line of the former. This adjustment is very critical and varies with different materials, gauges and diameter of tube. On very acute bends, or when using very thin gauge tubes in the region of 22 and 24 swg. the mandrel has the addition of one or more trailing balls or segments thereof attached by a flexible wire or chain (Fig. 6). Where these are used, however, a means of extracting the mandrel must be provided, as when the bending action is finished the balls are firmly gripped in the bend of the tube. The extraction may be carried out hydraulically, mechanically, or manually, as circumstances dictate. The mandrel and balls should be made of alloy steel and should be given a smooth polished finish. The amount of clearance allowed between the bore of the tube and the mandrel is important, and is in the region of .005″ to .015″. The mandrel should be suitably lubricated during the bending operation.

6. Filled Bending

For certain reasons, such as close proximity of bends to one another, bends not having a true radius, and compound bends formed in two planes, it may not be possible, or is uneconomical due to the cost of tooling, to produce bends by either of the above methods. In this case a filler is used, and this is usually either a low-melting point alloy such as Cerrobend, or Hoyt metal containing bismuth, lead, tin and cadmium, and which melts at 160°F. (in hot water), or a mixture of pitch and rosin, These are poured into the tubes in the molten state and allowed to solidify, being melted out again when bending is complete. Bending may proceed by machine as described under Section 4. If the bends are too complicated for machine bending, however, they are bent by skilled coppersmiths free hand, using whatever aids are possible. Either of these systems, however, are very much more costly than the other previously described.

7. Production Planning

The Order Department, having received the customer's order, produce the Works Order, copies of which are distributed to the Planning Department, Production Control Office, and wherever else necessary.

Production does not commence until the Planning Office have dealt with all preliminaries. These include requisitioning all materials and fittings on the Buying Department, and deciding what items shall be bought out, or made in the works, depending on the tools, machines and general capacity available. They determine the methods and machines to be used on production, and assess any special tools which it may be necessary to produce, passing the broad principle to be adopted to the Drawing Office, together with a requisition covering the supply of same. If necessary, they may be required to submit a detailed estimate of production, tooling and machine costs either for quotation purposes before the order is received, or as a basis for piece work rates and control of production costs.

The operations are then planned in detail and entered on a planning card (Fig. 7) against tooling and material requirements, together with times allowed

PLANNING CARD	DATE	FIRM	CARD No	
PART No			NO OF CARDS	
MATERIAL ÷		FITTINGS ÷		

OP No	OPERATION	TOOLS/MACHINE	PREP	TIME	GRADE
1					
2					
3					
4					
5					
6					
7					
8					
9					
		TOTALS			

FIG. 7

PART No ..... NAME ..... PERIOD .....

		JANUARY				FEBRUARY			
ORDER No	REQUIREMENTS								
	PROGRESSIVE TOTAL								
	DELIVERIES								
	PROGRESSIVE TOTAL								
	ADVICE NOTE								
	DATE								
	INDICATOR								
		MAY				JUNE			
ORDER No	REQUIREMENTS								
	PROGRESSIVE TOTAL								
	DELIVERIES								
	PROGRESSIVE TOTAL								
	ADVICE NOTE								
	DATE								
	INDICATOR								

FIG. 8

for the operations. These times may be obtained either from (a) standard times, (b) by estimate, in which case it is checked or proved in actual production before it is established, or (c) by a physical time check on a trial run, which, apart from established standard times, is the best and fairest way of all.

8. Production Control

Copies of the planning card are distributed to the Cost Office, Production Control Office, the Works Foreman's Office, and wherever else may be necessary. It is the responsibility of Production Control to organise the flow of work through the factory in such a manner that customer requirements are satisfied, delivery dates met, and a balanced production maintained. Instructions or advice on this matter will be forthcoming from the Sales Office and the Works Order Office, and the Planning Office who pass on information concerning customer's requirements, and production capacity.

This control is achieved through the use of delivery schedules, progress charts, and the issuing of job cards with instructions as to when they must be completed.

In many factories, the Progress Department is combined with Production Control, the responsibility of progress being to see that all requirements called up by Production Control are fulfilled. This is done by close co-operation with the foreman and production personnel, and by keeping a watchful eye on progress charts from which it can be seen if production is proceeding normally or lagging behind.

The majority of orders placed by a customer call for deliveries on a weekly or monthly basis at a given rate, until the order is completed. The first task of Production Control, on receipt of a Works Order, will be to fill in this information on a delivery schedule specially devised and printed for the purpose. Fig. 8 shows an abbreviated version of a typical example. The focal point in the schedule is the quantity required, shown weekly or monthly. Against these requirements are shown the actual deliveries made together with the progressive total. Using this schedule as a guide the job cards are made out, the total quantity being divided into batches on a weekly or monthly basis. The job cards (Fig. 9) are typed out in sets of four which include one white stiff copy for the Time Office, one buff stiff copy for Production, one white paper copy retained by Production Control, and one half-size paper copy to Cost Office. These cards and sheets have the various headings printed on them, which are filled in when they are issued. The top half of one side of all copies is identical, and contains all the common basic information, together with the job numbers. The other headings vary according to the different function which they have to fulfil. The information required is filled in under the various headings as production proceeds, and when the job is complete, these cards provide a complete record and history of its passage through the works. Details of all job cards issued will be entered on progress charts (Fig. 10) containing all basic information, such as name of firm, job number, quantity in batch, delivery period for completion, and headings for each operation. As operations are passed off by the Inspection Department, tickets are issued to that effect which are first handed in to Progress. This is entered on the progress chart and the tickets passed on to the Time Office.

When the completed items are despatched to the customer, an Advice Note is made out giving order number, part number, and quantity being delivered, etc. One copy is sent to the customer and copies distributed to various internal departments, including the Cost Office.

FIRM		PART No	
ORDER No			
BATCH No		JOB No	
NAME OF PART			
DATE	No ISSUED		QTY ORDERED
MATERIAL			
RELEASE No			
FITTINGS			
RELEASE No			

DATES	DELIVERY	ENDORSEMENTS	FINAL STAMP
REMARKS			

FRONT OF JOB CARD (SHOP COPY)

OPERATION	DATE	TIME	QTY.	NAME	B

BACK OF JOB CARD (OFFICE COPY)

FIG. 9

9. Costing

The functions of this department are manifold and include the assessment of manufacturing and actual costs, determination of working overhead costs, providing unit cost of production by analysis of all costs, providing advice to estimating department for dealing with quotations, to planning department in connection with the fixing of rates, and direct responsibility for all piecework or incentive schemes.

Copies of all paperwork dealing with outside purchases and stores requisitions, together with all the time booked against the order, are sent to this office where they are recorded in convenient form.

When the order is completed, this information is analysed, and the overhead costs added, giving the actual manufacturing cost per unit, and this is shown against the selling price quoted, or if no quotation has been made, the selling price is now determined.

The job record, as it may be called, is commenced, when one of the sheets of the job card set issued by Production Control is received in the Cost Office. This job sheet will give such preliminary information as name of firm, job number, order number, drawing or part number, quantity issued in batch, full quantity on order, together with full details of material issued by stores.

A copy of the planning card (Fig. 7) for this item will already have been received, and this will show the amount of time required for production, together with the grade of labour to be used, and details of tools and material requirements. In many cases, items are priced directly from the information on these planning cards before production commences. They will also have received copies of requisitions bearing the main order number for any material issued against tools, and copies of purchase orders, for outside purchases in this connection.

These orders usually show the cost of the items, although in practice the cost is not entered on the job record until the price has been ascertained from the invoice.

Whilst the job is in production, each operation is booked on at the Time Office by the operator concerned. The operator hands in to the time clerk the shop copy of the job card (Fig. 9) stating the operation being worked on, and whether starting or finishing. The time clerk records this information on his copy of the job card set, and also on a document called a summary sheet.

It may be several weeks before all operations are finished and the job completed. In order that costing may proceed apace with production, the Cost Office is furnished with details of all completed operations on a weekly basis. This is supplied by means of the summary sheet, a copy of which is made out for each operator engaged on production. This serves the

additional advantage of supplying information in connection with production bonus, enabling any time gained against time allowed, to be paid in the form of bonus each week. All operations are examined by inspectors as they are completed. In addition to entering in the quantity passed and placing their stamp or the job card against the particular operation, the inspector fills in a small ticket showing job number, "op" number, operator, and quantity passed. This is passed to Progress and Production Control, who enter information on their charts, and immediately pass it on to the Time Office. This enables the Time Office to mark up completed operations, and assess the time allowed for the quantity passed, crediting time saved for payment of bonus.

Any scrap which may be incurred, necessitating the production of further items and the issue of more material, is shown by inspection who issue rejection notes, a copy of which is sent to the Cost Office. Any further details which may be issued from the stores for incorporation in production, are issued on receipt of a requisition bearing the order number, a copy of which is sent to the Cost Office.

All this information, having been entered on the job record, will cover the direct manufacturing costs. In addition to these, however, many other indirect costs are involved, which have to be added to direct costs in order to find the actual costs. These include such items as salaries of all staff and non-productive workers, depreciation of plant, machinery, buildings, vehicles and consumable stores (where these are not directly chargeable to jobs); cost of maintenance of plant, buildings, vehicles, etc., cost of power, gas, all office requirements, consumable tools such as drills, dies, taps, cutting tools, saw blades, and all such expendable items needed either for the running of the factory or for use on production, but not directly chargeable.

A separate record is kept of these expenses, and at fixed intervals, such as three or six months, they are set against the direct manufacturing costs of wages and material, and the ratio shown as a percentage. This figure, called the overheads, will then be used as a basis for costing and assessing prices. Practice reveals that this figure varies tremendously between different firms, and may be anything between 100% to 600% of production costs. Usually, however, where the overhead costs are high, they are largely offset by the production costs being low. Among the reasons for the great variation in overheads are the type of production involved, whether a large turnover of small parts or low turnover of complex machinery, whether production is for the commercial market, or such as requires very high standards of accuracy involving a large inspection staff and equipment, such as for the aircraft industry; the amount of machinery, and mechanical handling devices, directly engaged on production, and the number of technical staff required on design, research and development. It will be readily realised that these conditions vary tremendously in different establishments and are such as effect overhead costs to a marked degree.

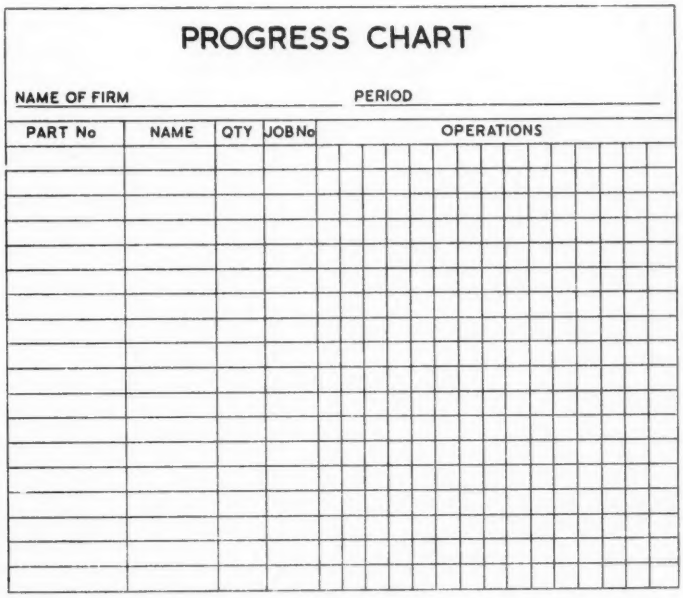


FIG. 10

HIGH PRODUCTION TOOLING FOR INDUCTION HEATING*

by C. E. GLICK, Production Engineering Manager; and

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Tocco Division, The Ohio Crankshaft Co.

SINCE its conception in the early thirties, the induction heating industry has grown to major importance and into a multi-million dollar operation each year.

The chief reasons are:

1. induction heating equipment is adaptable to most heating applications;
2. units are readily installed into high production manufacturing lines;
3. operating conditions are vastly improved over older methods;
4. substantial savings are possible by its use.

Design of proper tooling accompanying the basic induction heating equipment is one of the prime requisites to successful induction heating operation.

Before discussing the subject in specific detail, it might be well to review the principles of good design and the factors which would influence it. As an elementary definition, let us assume "design" to be an outline or pattern of something to be produced. It is the plan for the composition, form, structure, structural features, and appearance of the product. A well-designed product is one which will perform the service expected of it, which can be manufactured profitably and sold at a price which the consumer is willing to pay.

Factors Influencing Design

The factors chiefly influencing design are *function*, *maintenance*, *consumer's ideas*, and *materials*.

Function. Functional considerations are affected by the consumer's requirements and his willingness to pay for what he needs. A machine may be built for manual, semi-automatic, or automatic operation. It may be designed and built for intermittent, progressive, or continuous motions which may be vertical or horizontal. The unit may be built to last for a life time or for a day, It may be used to process parts at but a few pieces per hour or thousands per hour.

These and many other considerations are primary factors affecting design, apart from specifications for "job to be done."

Maintenance. Many products are used in locations where maintenance and repair are easily accomplished. Other products may be used under operations or conditions which make maintenance and repair difficult, if not impossible. A design which offers easy accomplishment of maintenance is definitely desirable from point of cost also. Many manufacturers, particularly when replacing equipment, are strongly concerned with the size and shape of the product in relation to plant layout and movement.

Customer Ideas. Consumers differ in their ideas concerning the design of a product. Some prefer a low-price product; some prefer quality. Some buy a product for extended use; some for short-time usage. The design, therefore, should be suited to the preferences of the group to whom the sales promotions are to be directed.

Availability and Use of Materials. The advent and passing of World War II produced quite a strain on the kind and quantity of materials available to private industry. The problem has been reduced but not removed. The problem promises to be a recurring one. During the War, many substitute materials were developed to replace materials which were difficult, if not impossible, to procure. Many of these materials and the changes in design to accommodate them have been made permanent.

Other factors could include the pressure of manufacturing to produce simplicity of operation. The sales manager may promote consumer preferences, regardless of costs. The president may insist on style. All of these factors influence design and the entirety may not be achieved.

The advent of induction heating produced an ideal tool particularly adapted to the new era of high-production methods. It also produced a process which accomplished work never before possible to perform.

Induction heating equipment is a tool which may be included in the "Special Machinery" class. Although the major components have been standardised, the tooling in most cases has not. This is due in part

* *Presented at the 22nd Annual Meeting of the American Society of Tool Engineers, and reproduced here by kind permission of the Society.*

to the wide variety of uses to which induction heating may be put, and in some instances to manufacturing processes or production demands.

Induction heating has been used to heat treat parts as small as a dime and as large as a car wheel. It has been used to heat treat tappets, tappet bodies, pump shafts, axle shafts, crankshafts, shot bodies, cartridge cases, cylinder liners, gears, sprockets, valves, and literally hundreds of other parts of assorted shapes and sizes.

From the foregoing it can readily be ascertained that those engaged in the process of manufacturing induction heating equipment are faced with the problem of wide diversity in design, which problem is complicated by preferred differences for processing by the consumer.

High Production Induction Heating Machines

A better understanding of high-production tooling methods for induction heating can be had by a description of several machines which have been manufactured for those in need of high production equipment.

Camshaft Machines. One of the earliest of these machines (1937), and the first large installation of camshaft hardening equipment, featured manual loading of two camshafts vertically into a fixture wherein the two-hole inductor indexed to the individual cams, eccentric, or gear, and performed the hardening operation. Approximately fifty pieces per hour could be processed by this machine, and a battery of these individual machines was installed to produce increased production, as required. Since these individual machines are but two feet long, several machines in a row do not occupy too much productive area (Fig. 1).

With this machine, the camshafts, after being loaded into the machine remain in position while the inductor and transformer assembly index from one area to another until the entire camshaft is heat treated. Motion of the inductor and transformer assembly is pneumatically performed on a pair of vertical guide bars. Indexing of this assembly was accomplished using an indexing bar. Different model camshafts could be readily accommodated by the simple expedient of replacing indexing bars. The machine base, spring load centre assemblies, and upper guide rod supports are machined castings. The entire assembly is covered by sheet metal with hinged doors providing ready access for maintenance and repair.

Maintenance and repair of these units may be carried on without seriously affecting production schedules because each machine performs a complete function. This, in addition to its diversity, has made it a valuable high-production tool.

A more recent camshaft induction heating machine which is used extensively, which produces hardened parts at a rate higher than the equipment just described, and which takes up even less floor space, is one wherein several inductors are installed into one machine. Each machine is equipped with three to

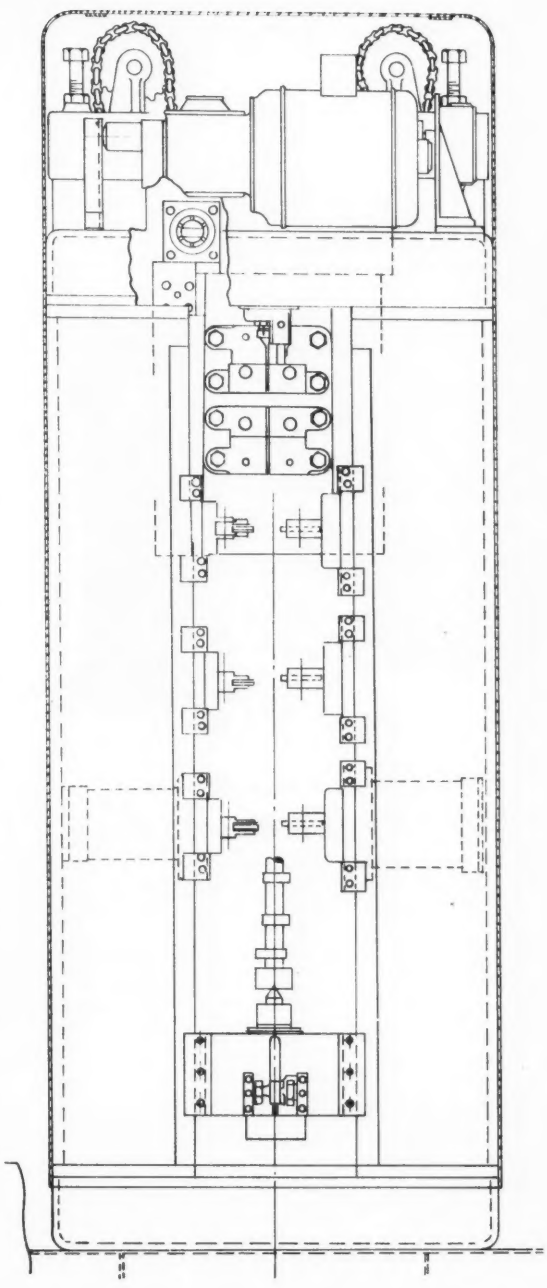


Fig. 1. Sketch showing positioning of camshaft and guides and retractable roller guides used during rotation.

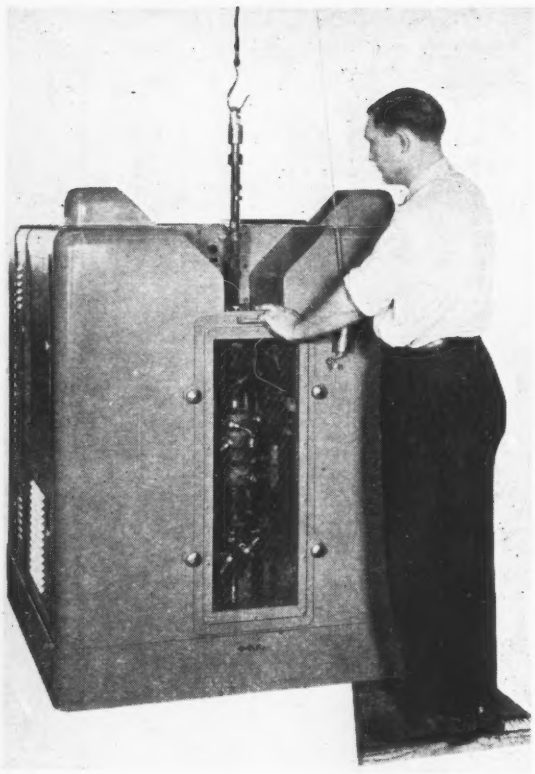


Fig. 2. Automatic camshaft hardening machine for hardening several cams simultaneously.

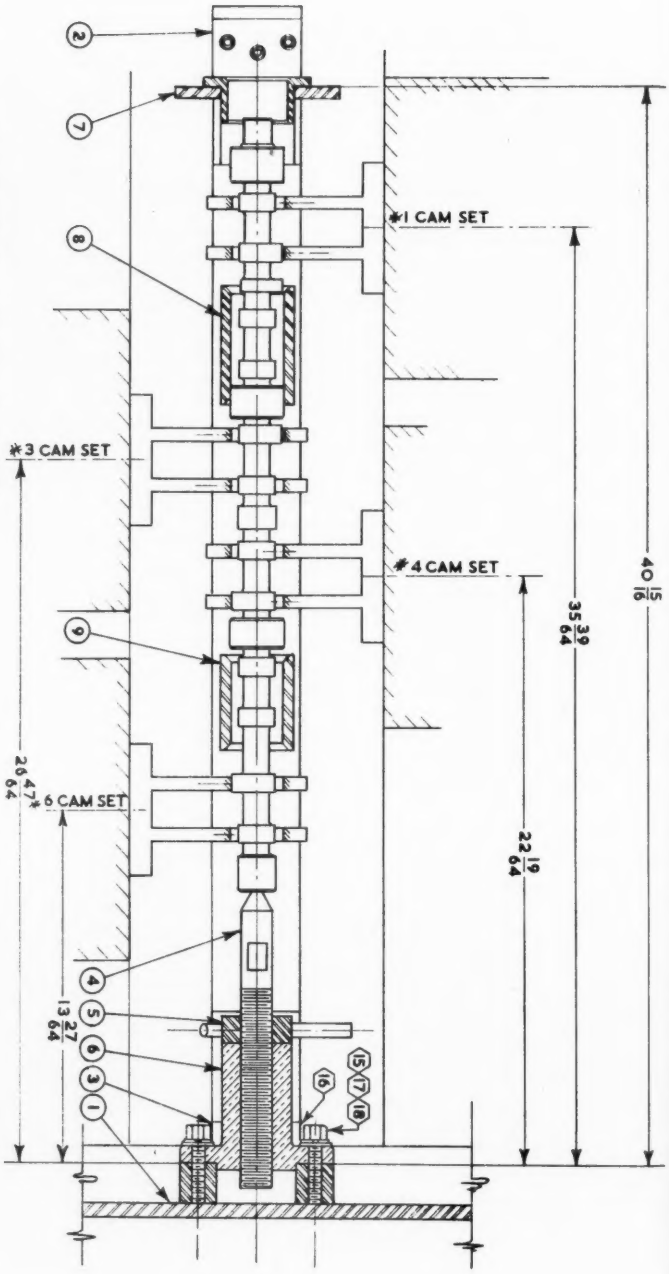


Fig. 3. Sketch showing positioning of camshaft and eight cams for hardening. The remaining cams and eccentric are shielded.

four high-frequency power transformers, capacitors, contacters, and timers for each. To each transformer is fastened a pair of inductors, each of which harden a pair of cams (Figs. 2 and 3).

Two machines are needed for completely hardening a camshaft, since one machine hardens but half the cam areas. The parts are loaded vertically by threading the part through circular guides. When the cycle in one machine is completed, the shaft is removed from the first machine and moved to the next machine where the remaining cams are hardened.

Particular attention was paid to use of materials in this machine. The camshaft is completely enclosed during processing, resulting in much water vapour during the quenching cycles. Materials, therefore, were non-corrosive; for example, stainless steels, cadmium plated tanks, etc., and non-ferrous metals.

These machines have been used quite successfully where high production and rough usage is anticipated. Processing of different-size camshafts is performed by adjusting height of transformer assemblies and hence the inductors, by screw adjustments which move these assemblies vertically to any desired location.

Many camshaft producers have need for a still different type of machine with greater versatility and/or for a machine wherein relatively few parts need be processed per hour. A standard unit capable of these functions, called a Toccotrol, has been in use for several years. This machine consists of a pair of centres mounted vertically on guide bars. The "Centre Assembly" is actuated by a screw drive, motivated by a direct current motor, and controlled by a Thymotrol drive. This machine is capable of performing many functions. A steady progressive motion, intermittent motions, various speeds with these motions, and various cycle controls of various degrees may be performed at almost any position during the scanning operations. The cycle for hardening a camshaft could be described as follows:

The camshaft would be loaded when the centres are in the upper loading position. When the operator pushes a starting button, the machine would index the camshaft into the first hardening position. In this position power would be applied, heating the cam area or areas, followed by a quenching cycle. Upon completion of the quenching cycle, the machine would index to the next area to be processed and so on until completion of all hardening operations. At the completion of the cycle, the part would be returned to the loading and unloading position. All the controls for the various operations are included in the Toccotrol unit, including power and quench controls.

Parts exposed to the use of water quench are made of materials not affected by water or other corrosive mediums. The guide bars are hard chrome plated, and the guide bar brackets are machined bronze castings. The screw actuating the "centre assembly" is an acme thread made of hardened steel and chrome plate. The screw nut is of Meehanite. On the whole this unit is very versatile and is used quite extensively progressively to scan and harden many varieties of applications.

One of the more recent induction heating developments now in use is a machine capable of selectively hardening a six-cylinder automotive camshaft at the rate of 300 pieces per hour (Fig. 4). The operator has but to keep this machine loaded and it will continue to process camshafts until the machine runs out of stock or the operator discontinues the operation.

The machine is simple but effective in design. The camshafts are loaded on to an inclined platform which allows the shafts to roll progressively into the loading position. At this point a pair of loading cams move the camshaft on to an upper pair of loading "vees". The "vees" move down into a position wherein centres pick up the camshaft, move it into the induction heating coil, rotate the part, and remove the camshaft to a set of lower "vees." These "vees" then lower into a position wherein the camshaft is placed on an unloading chute. The total time for loading, heating, and unloading is less than twelve seconds. The major motion of this machine — that of moving the part into the induction heating coils — is accomplished by an assembly of the centres on hardened guide bars. This assembly is actuated

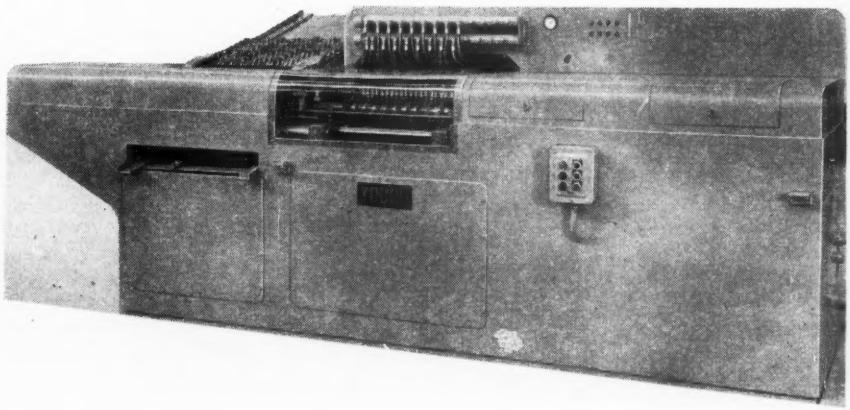


Fig. 4. Automatic camshaft hardening machine, capable of hardening 300 pieces per hour.

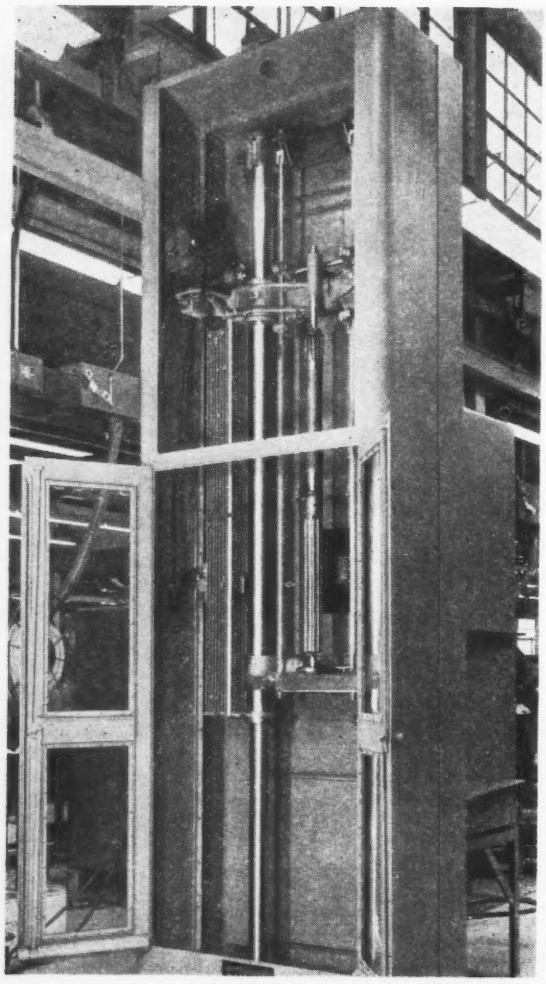


Fig. 5. Large axleshaft hardening machine, using Toccotrol fixture.

hydraulically. The right-hand centre is actuated individually to close on to the camshaft by the same hydraulic system.

As was noted before, the camshaft is moved into the field of a series of induction heating coils. At the same time, and during the heating cycle set up for the camshaft, the machine is automatically indexing for the next cycle. This machine has been designed to perform certain functional aspects which were necessitated by the consumers' demands and by the pressure of competition.

The prime requisite affecting the design of this machine was a minimum production of 240 per hour per machine. This was accomplished by extensive development of the inductor coils and by design of a machine which would perform the function of cycling at the required rate.

The motions of the machine consist of but four basic essential movements :

1. the major motion of the centring assembly moving alternately and in horizontal motion every cycle on hardened and hard chrome plated guide bars;
2. the vertical motion of the " vee " assembly of upper and lower " vees " also on hardened guide bars;
3. the set of " loading cams " which eject a single camshaft on to the upper "vees" and hold the next camshaft in to its " loading position " until the next cycle; these cams are hardened by carburising;
4. rotation of the part, which is accomplished by rotating the left hand centre by means of an electric motor with an integral speed reducer.

Cycling is accomplished by timers, limit switches and hydraulic control valves.

Maintenance of this machine is very simple since the motions are but few and the parts are readily accessible. Most of the mechanical components may be reached from the front of the machine and are placed at a good working height. The electrical control equipment and the high-frequency electrical power components are placed in a readily accessible cabinet which is integral with the machine. Quite naturally the size of this machine was held down to a minimum. Actually it takes up no more space than an average camshaft grinder and because of its construction can be easily moved to another location. Although material requirements are sometimes a problem of procurement, design and construction for induction heating equipment, none was evidenced in the design and construction of this machine.

The major bulk of this machine is of the metal-fabricating nature, made up of heavy angle and channel iron frame work, to which the fixturing is adapted and covered by heavy-gauge sheet metal. This rugged construction will easily withstand the rigours of continuous, rough wear to which the machine will be put.

The aforementioned are examples of how different types of tooling are designed to process the same part but are suited for the customers' needs.

Axleshaft Machines. Extensive use is now being made of induction heating equipment progressively to harden axle shafts of all types.

The Toccotrol, previously described, will perform the operations necessary successfully to harden axle shafts. The part is loaded between centres, control of fixture started, and the part progresses vertically downward through an inductor with an integral quench which impinges on to the heated part just below the inductor.

Flanged axle shafts are loaded in the down position of the fixture. When the cycle is started, the axle shaft is moved up into the starting position wherein the fillet area of the flange is statically heated momentarily. After a pre-determined time, motion downward is started and shortly thereafter a quench comes on which continues until the entire shaft, or whichever portion of the shaft is required, is hardened.

A variation of the originally designed fixture has been made for processing axle shafts weighing better than 100 pounds, or longer than 36″. This fixture is controlled in the same manner, but to the "centre assembly" is fastened a gear rack driven by a pinion on the D.C. motor drive shaft (Fig. 5). Two guide posts approximately 3½″ in diameter, hardened, and chrome plated, furnish support for the machined castings which house the upper and lower centres. The "centre" castings are made an integral assembly by being fastened in two lengths of steel tubing. Oilite bronze bearings inserts are used in each end of each tube. This entire assembly then slides on to the guide posts and is activated by a D.C. motor which is mounted to the "sliding centre assembly." Coupled to the motor is a pinion drive shaft, which pinions mesh with two gear racks (one fastened to each guide bar assembly).

The primary function of this machine is to provide progressive motion, so that axle shafts and the like may be heat treated for their entire length. One of the earlier axle shaft designs incorporated induction because of the following reasons: substantial cost reduction by use of plain carbon steels, elimination of various operations, and low unit cost at high productive rates. Added to these factors was the possibility of a fully automatic machine placed directly on the production line.

One such machine, designed and built by the Snyder Tool and Engineering Company and capable of processing 120 pieces per hour, features a six-station rotating assembly which is loaded with six axle shafts between centres (Fig. 6). As this assembly rotates, the axle shafts are guided progressively downward by a stationary circular cam track. As the axle shafts progress downward they pass through an inductor with integral quench. The transformers and inductors are contained within the rotating assembly. After completion of hardening, the axle shafts move progressively upward into the unloading position.

Several technical problems were encountered and overcome before the design of this unit was ultimately completed. Because the high-frequency transformer was installed in the rotating assembly, special high-frequency rotating contacts were designed and tested. It was also necessary to include in the design rotary pressure joints capable of carrying large volumes of water which is used to cool high-frequency components and to provide quench to harden the axle shafts.

Rate of travel (downward vertically) varies directly as the rotation of the assembly and contour of the stationary cam. It is necessary that rate of travel at different sections of the axle shaft be varied during processing. Thus the contour of the cam and rotational speed were very accurately held. Controls for the hardening unit are automatically actuated by limit switches, which are easily adjusted to accommodate axle shafts of various lengths.

The most recent ramification of the Toccotrol-type

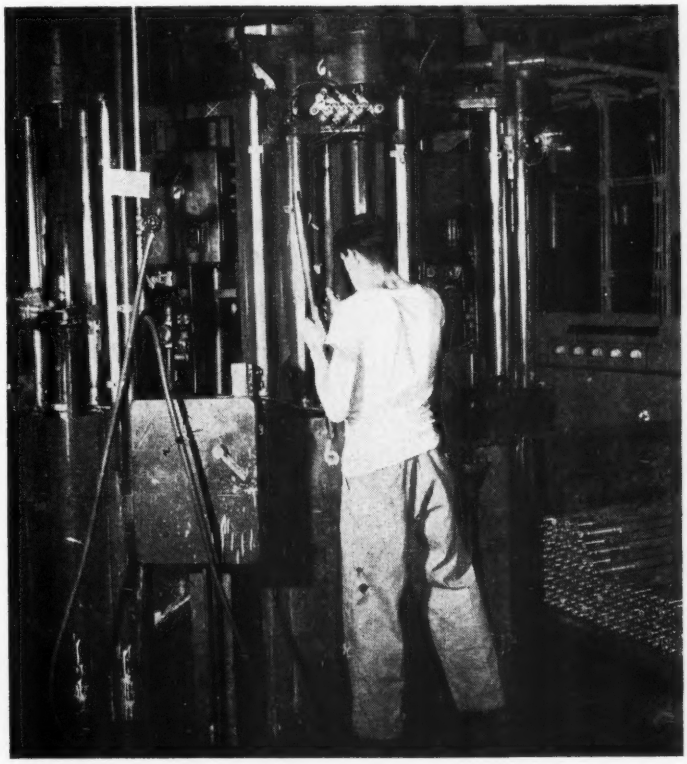


Fig. 6. Automatic axleshaft hardening machine, progressively heating and quenching 120 shafts per hour.

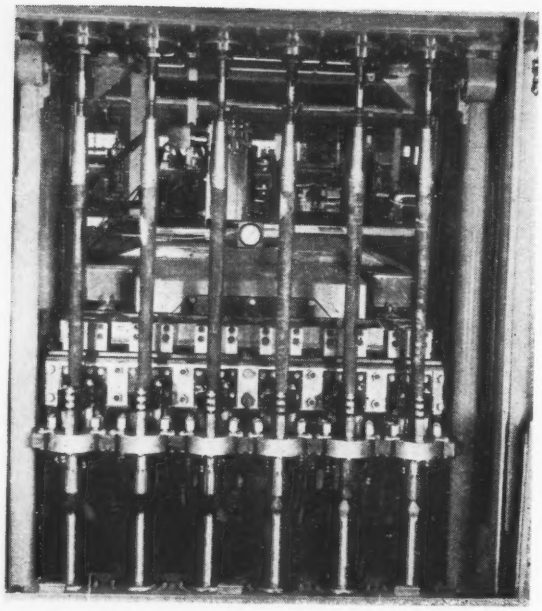


Fig. 7. Hardening six axleshafts simultaneously.

control was one designed and built for inductively hardening six axle shafts simultaneously (Fig. 7). This machine is almost fourteen feet high. Its guide bars are 4½" in diameter, made of 52100 alloy steel and inductively surface hardened and hard-chrome plated. It features retractable upper centres and retractable loading "vees." The guide post assembly and "centre assembly" are of heavy machined castings.

The entire machine is tilted at a slight angle to facilitate loading. In operation, the operator loads the machine when the "centre assembly" is in the "bottom" position. The axle shafts are loaded on to the bottom rotating centres and laid against "loading vees." The operator then pushes a button to start the cycle. The six upper centres thread through the inductor and move downward to engage the spline ends of the axle shafts. Immediately following, the "loading vees" retract and the parts are moved upward through the induction heating coils. This motion is relatively rapid and the time consumed is no more than a few seconds. Immediately upon reaching the upper extreme position, power is applied to a series of six inductor coils; the parts become heated; motion downward is started and progresses until the entire length of axle shaft has been threaded through the inductor coils and quench. When the shafts have reached the bottom, or loading position, power goes off, quench goes off, the "loading vees" engage the axle shafts, and the upper centres retract. The operator may then unload and reload for the next cycle.

As described in the previous description of scanning fixtures, motion is provided by a D.C. motor — in this instance h.p. — and powered electronically by a Thymotrol drive. The upper centres and "loading vees" are moved by air cylinders controlled by solenoid valves. Although designed for a specific axle shaft, this machine could be readily adapted to other shafts of varying dimensions.

Track Link Machines. A development totally different from those previously described is that of surface hardening the wearing surface of track links. Formerly these parts were processed inductively in a static position (Fig. 8) wherein the track link was held stationary under an inductor coil, heated, and quenched. One type of such fixturing was a wheel laid horizontally, on which several parts were loaded. The wheel indexed the part to its required positions.

The need for higher production at lower costs led to the development of a method for continuously hardening and drawing the wear surfaces of the track links. The fixture for this application consists of a continuous chain provided with adaptors upon which the track links are placed. The parts traverse the chain beneath induction heating equipment which heats for hardening, quenches and draws each successive part (Fig. 9). The fixture is simple in design and consists mainly of two lengths of channel iron, bushed on each end to accommodate the sprocket shafts and mounted on a suitable base. A three h.p. vari-speed drive is coupled to the fixture to provide continuous motion.

A production rate of 200 pieces per hour is easily obtainable on this machine. The loading and un-

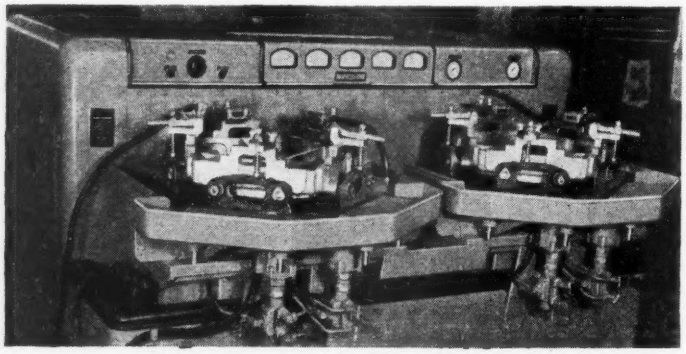


Fig. 8. Automatic indexing fixture for static heating and quenching of track links.

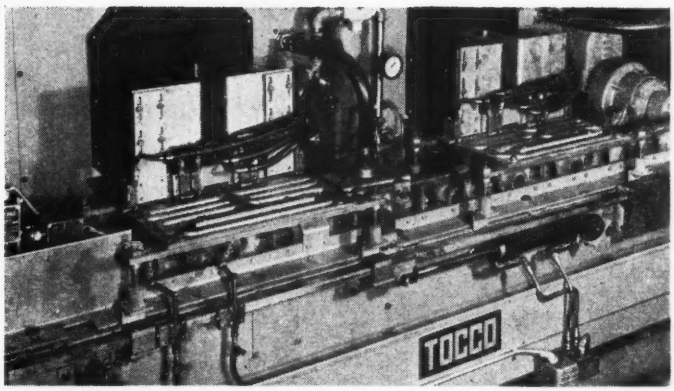


Fig. 9. Progressive fixture for continuous heating and quenching and drawing of track link surfaces.

loading platforms are at standard bench working height and maintenance of this machine is simple. All these features make this an ideal machine, fitted to high production method.

Track Pin Machine. A fixture which complements the track link machine is one for hardening track pins. It consists of a simple roller feed mechanism driven by a vari-speed drive. The rolls are arranged so that the track pins loaded into tube, progress vertically downward through "vee" guides, an inductor and quench, through "vee" rolls and out the exit chute of the machine (Fig. 10). Although this machine was not a challenge to design, it is interesting to note how well the use of induction heating equipment may be adapted to high-production tooling methods.

Before the advent of induction heating, track pins were of alloy and carburised with the usual machining and grinding operations. The material now used is the cheaper SAE 1050 steel of turned and polished mill stock.

This particular track pin machine is currently

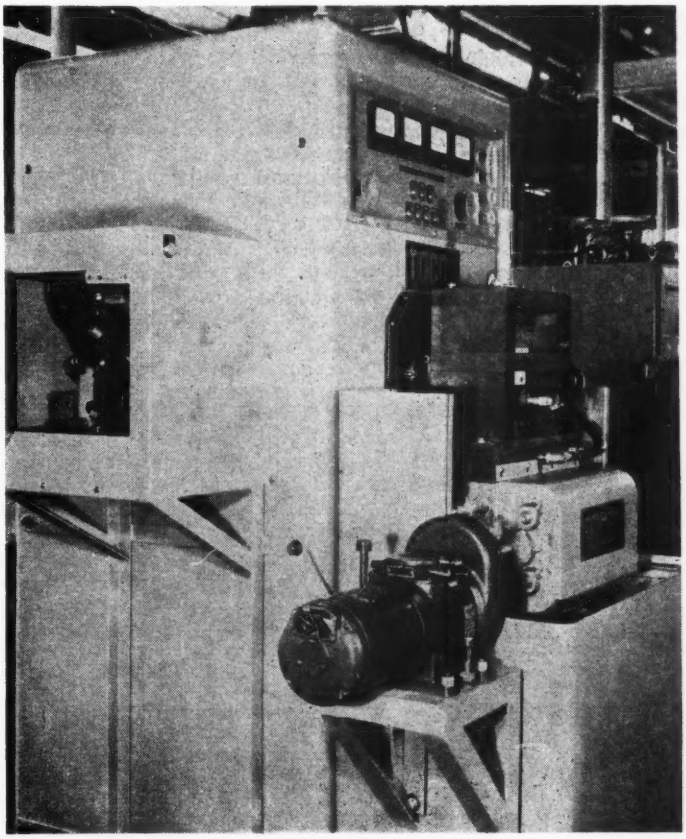


Fig. 10. Fixture for progressive heating and quenching of track pins.

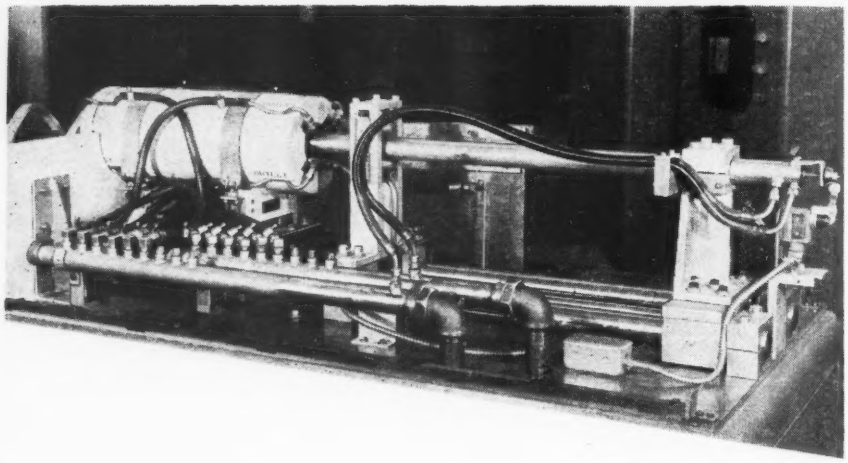


Fig. 11. Fixture for heating bars for forging, including automatic ejector.

being used in conjunction with completely automatic machinery which racks the stock, cuts to length, ends chamfer, deburs, degreases, induction hardens and packs for shipment. This is just one of many induction heating machines which fits ideally into high-production lines.

Forging Equipment. One of the more difficult forging applications recently designed for inductively heating bar stock is semi-automatic and almost entirely self-contained. The operation needed was to heat to forging temperature approximately 17″ of a $2\frac{3}{4}$″ dia. bar, 34″ long. After forging, the remaining half of the bar was to be inserted into the induction heating coil and the operation repeated.

The major problem associated with this installation was to provide facilities for loading and unloading which would prevent destruction of the inductor coil through rough handling. Other problems were conservation of space, low maintenance costs, selection of materials which would wear well, and materials which would withstand extreme thermal shock.

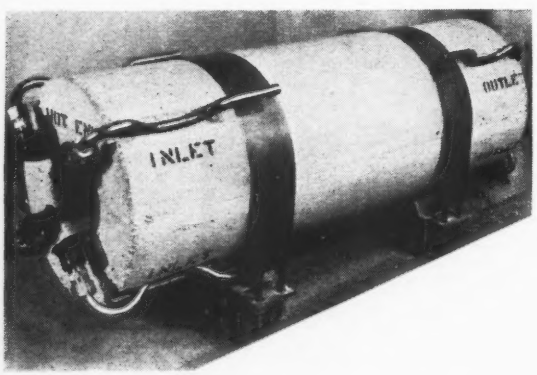


Fig. 12. Induction coil assembly, showing water-cooled guide rails made of Inconel tubing.

The unit consists of a cabinet in which the high frequency components are installed. The induction coil and the loading and unloading mechanism is installed atop the cabinet at proper working length (Fig. 11). The loading mechanism is simply "vee rollers" upon which the bars are rolled into the coil. Upper guides are provided to prevent unbalance of the bar causing damage to the inductor coil housing. The inside diameter of the inductor coil is lined with a silicon carbide liner, which will withstand the thermal shock of a relatively cold (90°F.) water-cooled induction coil on its outside and the extreme temperature of 2,200°F. on its inside diameter.

The bar is supported on square water-cooled Inconel tubing guide rails, which have been given proper metallurgical treatment to resist the wear caused by the motion of many parts over its surface. The present design of this inductor assembly (Fig. 12) is the result of a considerable amount of research and development to overcome operating difficulties and maintenance problems.

A water-cooled tube extending into the inductor coil opposite the loading end serves the triple function of locating the bar, indicating the condition of load or no-load, and ejecting the part. This ejecting tube is part of a movable assembly mounted on guide rods and actuated by an air cylinder controlled by a solenoid valve. Through the centre of the ejecting tube projects a rod, which is the means for actuating an interlocking switch which prevents application of power to the inductor coil in the event no part is in the coil. Some 30 units of this type have been installed and have proved to be the practical answer to most forging problems. To date some of these units have processed over 200,000 parts without need for repair or replacement of parts.

Materials

Induction heating has design problems peculiar only to this method of heating. The use of magnetic

(*concluded on page* 50

PRODUCTIVITY AND THE SECOND INDUSTRIAL REVOLUTION

Report of a discussion by a study group, led by Professor GOETZ, of Paris ; Mr. JOHN GRAY, of D.S.I.R. ; and Dr. T. U. MATTHEW, M.I.Prod.E., at the Alpbach European Forum, 1956.

The idea of a European Forum was originally conceived by the Austrian College Society in 1945 *and the* 1956 *Forum was the* 12*th in succession. It was attended by some* 400 *University Graduates and senior people, including over* 30 *University Professors, mostly in the fields of Arts, Economics, History and Political Studies and Pure Science. The basic purpose of the Forum is to bring together some of the leaders of thought from European countries, so that an effective understanding can be built up of the points of view held in different parts of Europe on modern developments in art, science, economics and political theory.*

If any Institution member would be interested in attending next year's Forum, Dr. Matthew would be glad to provide further information. He may be contacted through the Institution's Head Office.

1. The study group consisted of 26 members with a wide range of specialist interests and included a trade union leader, an industrial director, a financial expert, a psychiatrist and several industrial engineers, sociologists and economists. There was, therefore, a most fruitful discussion and clarification of the basic concepts which vary from country to country.
2. The subject was divided broadly for discussion to deal systematically with :
   (a) general economic and social questions;
   (b) industrial and human relation questions;
   (c) the effects of technological changes, such as automation on the one hand and the introduction of scientific management techniques on the other.

   This arrangement suited the special fields of interest of the three group leaders as well as the general interests during group discussions.
3. Some time was spent discussing the relationship between the industrial evolutionary process of the past two centuries and the accompanying revolutionary impact of industrialisation upon society, upon the structure of industrial organisations, and also upon the role of modern management and trade unions. The modern concept of increasing productivity as a means of increasing human welfare, was seen to be most important since it implies dynamic changes in the size and character of industries, changes in people's ways of working and living, and in industrial mobility; all such changes involving sacrifices for some to bring benefits to many.
4. It was agreed that these dynamic changes in industry, brought about primarily by each unit actively seeking to improve productivity, working conditions and earnings, and thus to contribute to raising the general standard of living of society as a whole, were essential. Changes of this nature were the inevitable consequence of international and national competition, and also of the impact of continuous scientific discovery and technological advances, none of which could be halted by the individual firm, even if it desired to do so!

   In this framework, the most important questions to be solved were not the technical problems of the engineer, but those of measuring productivity and of ensuring rapid progress from the economic, social and human standpoints.
5. This led to a discussion of the natural limitations to the rate of advance towards the automatic factory. An examination of the technical evolution of flow production, of the automatic transfer line, now used successfully in the automobile industry, and of automatically controlled plant units in the chemical and other process industries, led to the conclusion that the completely automatic factory operated by one man was a pipe dream which practical realities in the shape of instrument and plant maintenance needs must dispel. The conclusion was also reached, however, that as mass-production, based upon consumer demand for standard products, allowed more and more operations to be carried out by automatic machines, so the nature of factory work would change. A greater proportion of the labour force in such factories, would be required to supervise, regulate, maintain and build specialised automatic machinery and fewer unskilled repetitive manual operators would be required.
6. The main limitations to progress in this direction were seen to be economic and social and not technical, except insofar as more technical education and training would be required for a larger percentage of the working population. The problem of designing job requirements in relation

to the level of skill and intelligence in the population, may thus assume greater practical importance in the future.

7. Automatic factories require much more capital per operator than manual work and problems of economic balance between the different sectors of national economies are thus likely to emerge and to engage increasingly the attention and skill of governments and industrial leaders.
8. Apart from economic limitations to industrial progress, probably the most serious limitation is the basic psychological resistance to change which is an inherent characteristic of us all.
9. Progress means change, change not only in equipment and materials but also for the individual worker, who must learn new skills and new arrangements in his working group and in the management structure. Modern management and trade union thinking recognise the need for leadership and for psychologically sound preparation for changes, however small, so that a minimum of human misunderstanding or social disruption occurs.
10. It is the realisation of human needs for security and satisfaction in work that has led to increasing attention being focussed, by industrial and trade union leaders, upon social problems of mobility of labour and redundancy due to technological change.
11. These problems require a new understanding of human and social psychology and certainly the development of more effective means of communication and consultation within industry for progress to be maintained within a framework of good human relations.
12. Recently, in many European countries, industrial and trade union leaders have accepted a new role in working together to accelerate progress towards higher productivity, through the use of electronic computers and automation, through a more systematic use of modern techniques of management and through the improvement of human relations in industry.
13. It is this acceleration of change, linked as it is with the development of atomic energy, and the emergence of new synthetic materials, that has given rise to the concept of a second industrial revolution. Whether or not the actual trends justify this title, it is hard to say. Technological change has followed an evolutionary course, but its impact on society has been in many ways revolutionary and it has raised possibilities of a rise in productivity and living standards more widespread and continuous than ever before.

" HIGH-PRODUCTION IN TOOLING FOR INDUCTION HEATING " —(*concluded from page* 48)

materials and other metals in close proximity to the field of induction heating coils must be avoided where possible, since inductive heating of these materials will occur. For this reason, many electrical devices must be provided to forestall deleterious heating effects upon fixturing and component parts. These methods may include electrical shielding, isolation or " breaking up " of circuits through which induced currents may flow or through localised heating controls. It is sometimes impractical to design around these problems, in which cases a design must be devised which will provide cooling to the affected parts.

Insulating materials play a large part in the successful application of induction heating equipment. Extensive use has been made of ceramics capable of absorbing extreme thermal shock, as in the case of forging applications. For instance, in a typical forging installation, a ceramic must withstand temperature difference of 2,000°F. within a $\frac{3}{8}$" wall thickness. Other insulating materials must not only provide high dielectric strength, but must withstand high voltages at elevated temperatures in the presence of steam and water. Still other insulating materials must withstand extreme voltages in the range of 10,000 to 12,000 volts.

Some of the old stand-bys are still used extensively, such as asbestos-base materials, and linen and glass base laminates. The plastics available today in wide variety of chemical compositions and formulated for particular uses are making a big inroad as engineering materials, however. Some of these plastics, such as the silicones and epoxy and melamine laminates, in addition to being very good insulators as such, have extremely low moisture absorption properties.

The inherent problems affecting the choice of materials for induction heating equipment are essentially the same as those of the design of any other machine tool. These factors might include the qualities of the materials, availability, cost and manufacturing procedures. With but very few exceptions, no concessions can be made for the quality of the materials specified by the engineering department. Cost and manufacturing procedures play a very minor role in selection of induction heating materials, mainly because relatively small quantities or units are processed. Availability has been, and still remains, one of the major design problems with its subsequent effect upon delivery of induction heating equipment.

Conclusion

As has been indicated in the previous discussion, induction heating is a relatively new field. It has expanded rapidly since its conception in the early '30's. Standards for equipment have been made but are viewed as " temporary and dynamic " rather than " permanent and static ". New methods and processes of manufacture in all industries are demanding flexibility and fluidity in design from induction heating equipment. The induction heating industry has thus far kept abreast of new developments and, in many instances, has lead in the adoption of induction to these new developments.

Tooling for induction heating for high production applications is in the same class as that for a machine tool, requiring the same techniques of design with one exception. We are also faced with the handling of heated parts — a new challenge to the tool engineer.

Production Engineering Research Association of Great Britain

Quarterly Newsletter to the Institution

Annual General Meeting

The 11th Annual General Meeting of the Association was held at Melton Mowbray on 10th July, 1956. Sir William Stanier, F.R.S., was re-elected President of the Association and the following were elected to PERA Council: Mr. W. A. Clark (Beatson Clark & Co. Ltd.), Mr. W. M. Hurton (English Electric Co. Ltd.), Mr. T. R. Swift (Powers-Samas Accounting Machines Ltd.) and Mr. J. H. N. Thompson (John Thompson Ltd.).

The Chairman's Report stated that 33 general investigations were carried out during 1955 on machining, pressworking, machine tools, thread rolling, impact extrusion, tool grinding, de-burring, cutting fluids, etc. One hundred and forty practical investigations were carried out for individual members. Very heavy demands were made on the technical enquiry service, and approximately 1,700 separate enquiries on a wide variety of production problems were answered. The collection of books, standards, pamphlets, directories and reports in the library was increased by 865 items during the year, and the number of technical journals received increased to 484 per month. Nearly 8,000 books, etc., were loaned to members during the year. About 5,500 copies of the Bulletin were issued each month, and over 59,000 reprints of articles were supplied to members. Income during the year increased by more than £28,000 to £159,289, mainly as a result of subscriptions from new members, donations by members to the general funds, and additional D.S.I.R. grant. It is anticipated that industrial income in 1956 will exceed £95,000, and this will mean that the whole of the D.S.I.R. revenue grant will be earned.

Monthly Bulletin

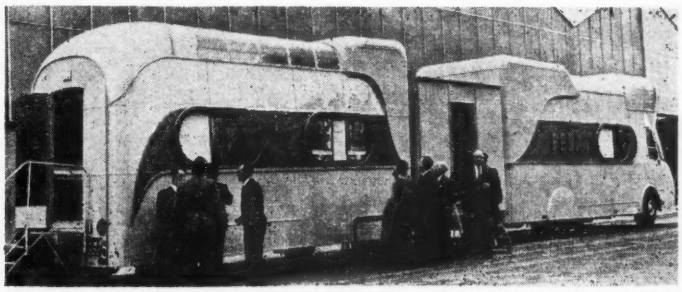
The fourth part of PERA's 'Guide to the De-Burring of Machined Components' was summarised in the July issue of the bulletin; 1,200 copies of this report were issued to member firms in September. The report describes the design and application of a wide range of power-operated de-burring equipment. Specific examples are given of current practice in removing burrs from holes, slots, edges and faces, gears, screw threads, and tubes. Savings arising from the use of methods described in the report include a reduction in the time for de-burring gears from three minutes to 18 seconds per gear.

The September issue of the Bulletin contained a summary of a report on the accuracy and performance of small drills. The first part of the report gives the results of an investigation into the accuracy of British and foreign drills. The second part deals with the effects of cutting speed and feed rate on drill performance when drilling steel. The investigation revealed that there is a marked increase in drill life at a critical feed rate, irrespective of the cutting speed within the range used in the tests.

Research

An investigation into barrelling (the fifth in the series on de-burring) has been completed, and the report is now being prepared for publication. A report has also been completed on the de-burring of metal pressings. This report is based on a study of de-burring practice in industry, and on a survey of published information.

Preliminary practical tests are in progress to determine the effects of cutting fluids and methods of application when turning alloy steels with carbide tools, and stability devices are being developed to eliminate self-excited chatter when using large overhanging boring bars. Work has been completed on the first part of an operational research into applications of work positioning and handling equipment for reducing or eliminating manual operations. Substantial progress has also been made in an investigation into various aspects of machine tool slideway lubrication. The first part of the investigation has been completed, and a draft report is being prepared on the influence of ground and scraped surfaces, lubricant viscosity, load per unit area, and sliding speed on the transition from boundary to hydrodynamic lubrication. Practical tests are also being carried out to determine the boundary friction properties of various lubricants and slideway materials for machine tools.



PERA mobile demonstration unit during a visit to Bristol Aircraft, Limited.

CASE STUDY No. 10

Assembly of Plastics Door Furniture.

Source: **Ipescomating Enterprises.**

Author: **A.M.I.Prod.E.**

An example of Materials Handling during operations.

In common with this company's policy of general development, this study is an example of improving the efficiency of an assembly operation and reducing the operator effort — 'making it easier' by handling material more effectively. The development policy is of balanced efficiency of operations rather than an effort to achieve a near 100% for each job studied. In this way greater benefits are achieved from the efforts of the study engineers. An average of 85% is considered reasonable, and this proves more economic for a given outlay of time and money since more can be done.

A later review takes into account recently developed potential such as product development, process development, handling equipment, and new ancillary devices, all of which can materially effect any particular job, and reduce handling still further.

Assembly of Plastics Door Furniture

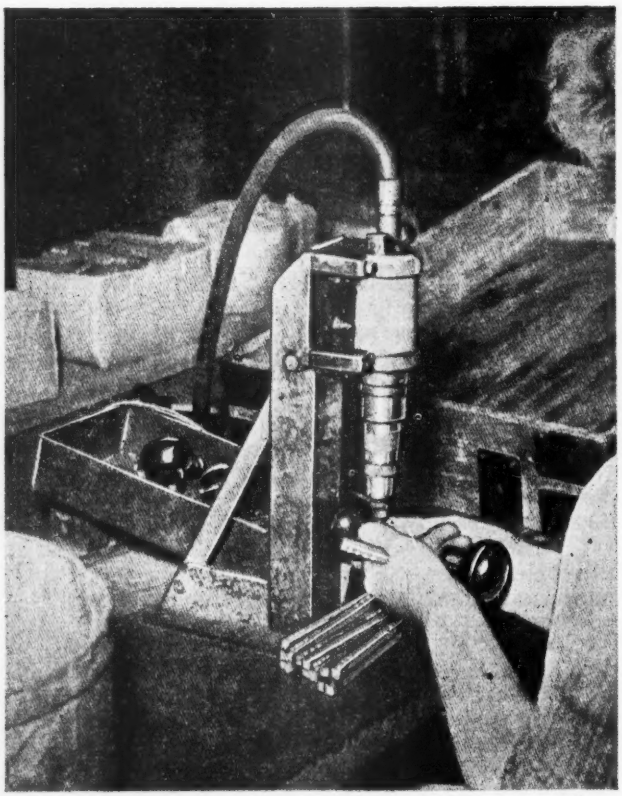
For convenience of packing and handling by user, and as an additional inspection, two plastics door knobs are positioned on the mild steel spindle and a screw inserted through each knob into the spindle.

old method

A bracketed pneumatic screwdriver, mounted at a convenient position and running all the time, rapidly tightened a c/sunk headed screw in each end which had been started by hand.

1. *Knob picked up — right hand from tray on right.*
2. *Spindle picked up — left hand from centre front.*
3. *Spindle inserted into knob.*
4. *Screw picked up from tray—right hand from tray, centre.*
5. *Assembly in left hand — screw in right — start screw.*
6. *Present to pneumatic screwdriver and tighten—both hands.*
7. *Turn assembly round — hold in left hand.*
8. *Pick up knob, right hand.*
9. *Assemble on to other end of spindle.*
10. *Pick up screw, right hand.*
11. *Start screw.*
12. *Present to screwdriver and tighten.*
13. *Dispose on to conveyor — Back.*

TOTAL TIME :- 17 *seconds.*



HANDLING

new method

Two pneumatic screwdrivers mounted on a bracket, one fixed, one floating, compensate for slight centre differences, and both are adjustable for other jobs at different centres.

Simple fixture, locating spindle with hinged end stop, and two light spring-loaded balls for locating and holding spindle; one bracket of fixture is adjustable to accommodate other spindle lengths.

Hinged centre tray for holding spindles, and adjustable for correct gravity presentation.

Hinged tray is adjustable at the back for variation of presentation angle. Knobs are emptied into the large free area at the back, and split into two streams at a convenient location position by each hand.

A combined foot rest and air valve causes the fixture to lift by air cylinder and feeds air to the screwdrivers only when in use, and this enables two screws to be tightened into the spindles simultaneously.

This individual unit was painted light green and mounted at right angles to a conveyor belt, which transported the completed assembly to the inspector.

1. Pick up spindle, right hand, and locate in fixture to stop.
2. Left hand flicks stop away.
3. Two knobs inserted over each end of spindle, right hand and left hand.
4. Two screws picked up, right hand.
5. Both screws started.
6. Fixture and spindle/knob assembly pushed up to screwdrivers, right foot.
7. Complete assembly placed on to conveyor, left hand.

TOTAL TIME:- 13 *seconds.*

Summary of Advantages.

1. Increased output per operator.
2. Improved standard for Departmental Handling.
3. Less space required for given output.
4. Less operator fatigue.

Cost and Method

Installation

A wooden model fixture was prepared and demonstrated at a TWI Job Methods course, and later demonstrated to senior executives, where sanction for manufacture was obtained. The completed unit was proved in the development section with a production operator before final installation. At a later date, three more units were built.

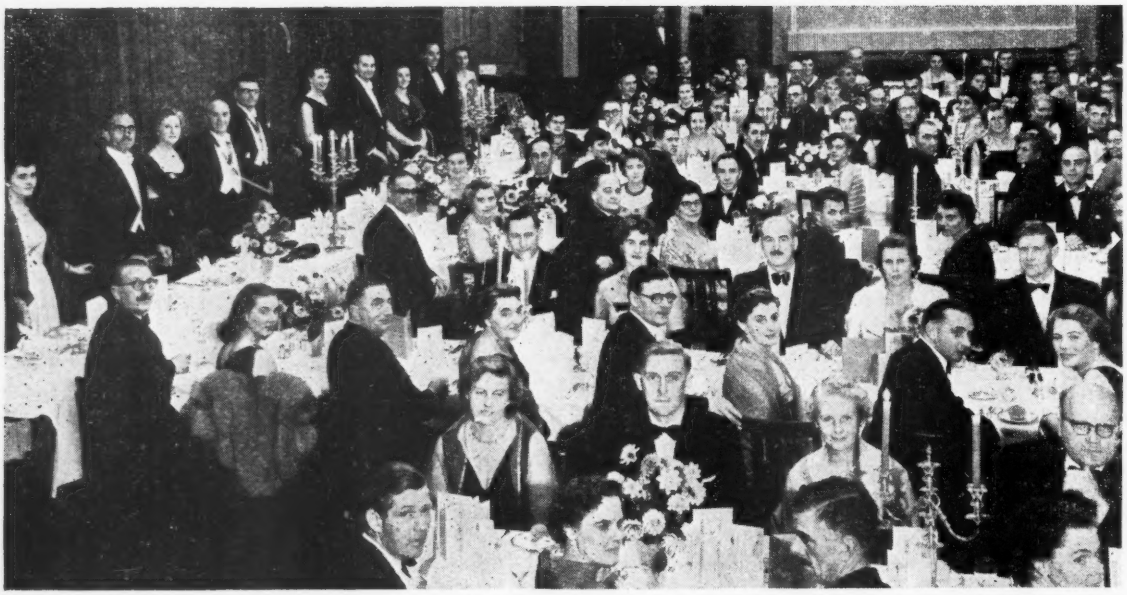
Cost per Unit approx. £150

Conclusions

The principal installation difficulty was persuading operators that they would eventually start two right hand screws, one with each hand, without difficulty.

This Company is busy improving other departmental handling problems to a similar standard. When all processes have been 'balanced', a further programme will be undertaken in view of more recent developments. (i.e. hopper feeding, new materials, automation).

institution notes



The President of the Institution, Mr. E. W. Hancock, M.B.E., and Mrs. Hancock were the principal guests at the Western Section Dinner held on 25th October last. Also present were Mr. W. F. S. Woodford, Institution Secretary, and Mrs. Woodford.

The photograph on the left shows Mr. J. R. Widdowson, Chairman of the Sheffield Section, with the principal guests at the Section's Annual Dinner on 8th October last. From left to right (front) are the President of the Institution, Mr. E. W. Hancock, M.B.E.; the Lord Mayor of Sheffield; Mr. Widdowson; the Master Cutler; Sir William Stanier. At the back, from left, are: Mr. H. Crompton (Yorkshire Section Chairman); Mr. J. A. McWilliam; Mr. W. A. Hannaby (Halifax Section Chairman); and the Chairman of Council, Mr. H. G. Gregory.

On 9th November last, Sir Walter Puckey, Immediate Past President, addressed the Eastern Counties Regional meeting on "Automation — Does It Concern You?" This photograph, taken at the meeting, shows (from left) Mr. L. A. Childs (Eastern Region Hon. Secretary); Mr. V. Crowther (Norwich Section Chairman); Mr. H. H. Dawson; Mr. F. T. Dyer (Eastern Counties Section Chairman); Sir Walter Puckey; and Mr. E. N. Farrar (Eastern Region Chairman).

Mr. W. G. Ainslie, Member, has relinquished his appointment as Head of the Department of Production Engineering and Management of the Wolverhampton and Staffordshire College of Technology, and has taken up an appointment as Lecturer in the Department of Engineering Production at Birmingham University. Mr. Ainslie serves on the Research and Education Committees of the Institution.

Mr. D. Gemmell, Member, has relinquished his position with Metal Industries and has now joined the Plessey Group as a Management Executive on the personal staff of one of the main Directors.

Mr. A. Griffiths, O.B.E., Member has recently taken up an appointment as Director and General Manager of The Daimler Company Limited, Coventry. He was formerly Director and General Manager of F. Perkins Limited, Peterborough, and served with the Ford Motor Company for 17 years before joining the Perkins organisation. During his nine years with F. Perkins Limited, Mr. Griffiths played a significant part in the post-war expansion of the Company.

Mr. W. Gwinnett, Member, Managing Director of Rubery Owen & Kemsley Limited, has been elected President of the Australian Council. He was trained as a mechanical engineer, and joined the Rubery Owen organisation in England as a designer draughtsman in 1932. During 14 years of service he progressed through various aptitudes to the position of assistant general works manager at the Darlaston enterprise, which at that time employed more than 6,000 people. He went to Australia in 1947 as Director and Works Manager of the newly-formed organisation at Finsbury. He became Managing Director in 1949. Mr. Gwinnett was the first President of the Adelaide Section of the Institution in 1951-52, and is a past Chairman of the Australian Council. He has taken a prominent part in Institution affairs and in the Chamber of Manufacturers and other industrial activity in South Australia.

Mr. J. D. Pearson, Member, has now joined the Board of Sentinel (Shrewsbury) Limited. He is Deputy Chairman and Chief Executive of Rolls-Royce Limited.

Mr. J. Baker, Associate Member, has taken up an appointment as Chief Production Development Engineer with Rotol Limited, Gloucester.

Mr. L. G. Berry, Associate Member, has left his position as New Projects Planning Engineer with Rootes Limited, Export Division, and has taken up an appointment as Production Manager with Colt Ventilation Limited and W. H. Colt (London) Limited of Surbiton.

Mr. H. Bolton, Associate Member, has been appointed Senior Lecturer in the Mechanical Engineering Department of Huddersfield Technical College.

Mr. W. Charlson, Associate Member, has recently taken up a position as Engineer I with the Naval Air Department of the Royal Aircraft Establishment, Bedford.

Mr. A. Hollen, Associate Member, has taken up an appointment as Production Machine Shop Manager with Bristol Aero-Engines Limited.

Mr. P. Iredale, Associate Member, is now Works Engineer with M. & G. Thynne Limited, Hereford.

Mr. E. G. R. Jones, Associate Member, has relinquished his position as General Manager with the Cardiff Works of The Lancashire Dynamo & Crypto Co. Limited, and has taken up an appointment with Messrs. Nettlefold Stenman Hinges Limited, Cardiff, as Production and Maintenance Engineer.

Mr. T. B. Maddison, Member, has been appointed to the post of Carriage and Wagon Development Engineer, British Transport Commission, and will be located at Stooperdale Offices, British Railways, Darlington.

Mr. A. Poole, Associate Member, has relinquished his appointment with Associated British Machine Tool Makers Limited, and has now taken up the position of Personnel Assistant to the Managing Director of J. W. Jackman & Co. Limited, Manchester.

Mr. F. W. Shoemack, Associate Member, has now retired from Philips Hamilton Works Limited and from further active participation in the engineering industry. Mr. Shoemack has been associated with the Philips Group of Companies on matters of production tooling and management since May 1934 until the end of September 1956, when he retired at the age of 68 years.

Mr. O. E. Trivett, Associate Member, has recently resigned from the Board of Aerialite Limited, Cheshire, to take up an appointment as General Manager of McMichael Radio Limited, Slough.

Mr. F. E. Taylor, Graduate, has been promoted to Assistant Engineer (Specialist Engineer 6) at the National Coal Board, Central Engineering Establishment, Stanhope Bretby, near Burton-on-Trent.

Mr. T. Thompson, Graduate, has now relinquished his position as head of the Materials Handling Division of International Equipment Pty. Limited, a subsidiary of Email Limited, and has taken up a position as head of the time study, methods study and projection engineering departments of Messrs. Johnson & Johnson Pty. Limited, of Botany, N.S.W.

Mr. E. Thorne, Graduate, has relinquished his position as Assistant Works Manager with Cylinder Components Limited, and has taken up the appointment of Production Manager with Messrs. Preston, Bishop Limited, Bromsgrove.

Mr. R. J. Watkinson, Graduate, is now with E. W. Bliss (Eng.) Limited, as a Designer Draughtsman in the Hydraulic Division.

NOTICE OF ANNUAL GENERAL MEETING

NOTICE is hereby given that the Annual General Meeting of the Institution will be held at 10, Chesterfield Street, London, W.1, on Thursday, 31st January, 1957, at 2 p.m.

Agenda

1. Notice convening Meeting.
2. Minutes of the Annual General Meeting held on 26th January, 1956.
3. Report on Elections of Members to Council.[1]
4. Annual Report of Council.[2]
5. Presentation of Statement of Income and Expenditure, Balance Sheet and Auditors' Report.[3]
6. Election of Auditors, 1956/57.
7. Election of Solicitors, 1956/57.
8. Vote of Thanks.

By Order of the Council.
W. F. S. WOODFORD, *Secretary.*

1. See page 57.
2. See page 58.
3. See page 66.

MINUTES OF THE ANNUAL GENERAL MEETING

held on Thursday, 26th January, 1956

THE thirty-fourth Annual General Meeting of the Institution was held on Thursday, 26th January, 1956, at 2 p.m., at the Headquarters of the Institution, 10 Chesterfield Street, London, W.1. The Vice-President, Mr. E. W. Hancock, M.B.E., was in the Chair.

Notice convening Meeting

The Secretary (Mr. W. F. S. Woodford) read the notice convening the meeting.

Minutes of Previous Annual General Meeting

The Minutes of the previous Annual General Meeting, held on 27th January, 1955, were taken as read and confirmed on the motion of Mr. B. G. L. Jackman, seconded by Mr. F. T. Nurrish, and were signed as correct.

Election of Members to Council

The Report on the Election of Members to Council was received on the motion of Mr. C. C. Cornford, seconded by Mr. W. Abraham.

Annual Report of Council

Mr. G. R. Pryor (Chairman of Council), moved the adoption of the Annual Report.

Mr. H. G. Gregory seconded the motion.

The Chairman invited questions or comment, and, none being forthcoming, put the motion for the adoption of the Report, which was carried unanimously.

Statement of Income and Expenditure, Balance Sheet and Auditors' Report

On the motion of Mr. H. G. Gregory, seconded by Mr. A. Betts Brown, the accounts were adopted unanimously.

Election of Auditors, 1955/56

On the motion of Mr. F. W. Cranmer, seconded by Mr. A. S. Johnstone, Messrs. Gibson, Appleby & Co., Chartered Accountants, were re-elected Auditors to the Institution for the year 1955-56 and thanked for their previous services.

Election of Solicitors, 1955/56

On the motion of Mr. H. Burke, seconded by Mr. E. P. Edwards, Messrs. Syrett & Sons were re-elected Institution Solicitors for the year 1955-56 and thanked for their previous services.

Vote of Thanks

The Chairman moved a vote of thanks to the immediate Past President (Sir Walter Puckey), the Chairman of Council (Mr. G. R. Pryor), the Vice-Chairman of Council (Mr. H. G. Gregory), and all the other officers of the Institution for their leadership and conduct of the Institution's affairs during the year. He wished also to include in the vote of thanks the staff of the Institution.

Mr. E. N. Farrar seconded the vote of thanks, which was carried with acclamation.

Mr. G. R. Pryor, responding, said he was sure that Sir Walter Puckey would wish to join with him in expressing appreciation of what had been said.

Mr. H. G. Gregory, who also responded, expressed his gratitude for the kind words which had been said and for the way in which they had been received by the meeting.

Mr. J. E. Hill, moved a cordial vote of thanks to Mr. Hancock for taking the Chair, which was carried by acclamation.

The meeting then terminated.

REPORT ON ELECTION OF MEMBERS TO COUNCIL 1956/57

In accordance with Article of Association No. 34, there were nine vacancies for elected Members of Council (eight Members and one Associate Member).

For the eight vacancies for elected Members 22 nominations were received. As a result of the ballot conducted in accordance with Article of Association No. 43, the following were elected:

Mr. H. W. Bowen	Mr. S. J. Harley
Mr. H. Burke	Mr. H. W. Hodson
Mr. F. J. Everest	Mr. A. L. Stuchbery
Mr. A. Griffiths	Mr. C. Timms

For the one vacancy for the elected Associate Member, four nominations were received. The Associate Member elected was:

Mr. L. S. Pitteway

Ballot papers were circulated to 5,653 Corporate Members in the United Kingdom. Details of the voting issued by the Institution's Auditors are as follows:

Eligible papers included in the ballot		1,453
Rejected:		
Incorrect number of votes recorded	26	
Papers not marked in ink ...	14	
Envelopes unsealed	2	
Insufficiently stamped — returned to G.P.O.	4	
Received from G.P.O. as unable to deliver	5	
Papers received after closing date	27	
	—	78
		1,531

The full list of Council Members for the current year is published in the Journal.

REPORT OF COUNCIL

1st July, 1955 to 30th June, 1956

TO BE PRESENTED BY THE CHAIRMAN OF COUNCIL AT THE ANNUAL GENERAL MEETING
Thursday, 31st JANUARY, 1957.

IN presenting to you the report of the Council for the year ended 30th June, 1956, I do so with mixed feelings of pleasure and of disappointment. The pleasure is occasioned because I am able to report steady progress in our affairs and I can do so without seeming to be complacent, since our affairs during the period under review were under the direction of my predecessor in office, Mr. G. Ronald Pryor. I cannot speak too highly of the work which Mr. Pryor has done for this Institution over a period of very many years. He has set a standard of performance for Chairmen of Council which very few will be able to emulate. He has been unfailing in his attendance at meetings and has put in endless hours of hard work between meetings. His skill as a Chairman in steering difficult meetings through troubled waters is unmatched. When the constitution of the Institution was modified a few years ago, the Council in their wisdom decided that the immediate past-Chairman of Council should remain as a member of Council in that capacity and I am indeed grateful that I am able to refer to Mr. Pryor for advice and guidance.

The disappointment to which I refer arises from the fact that we were compelled to increase the annual membership subscription during the year. I shall enlarge on this in greater detail when I deal with the Institution's finances later in the report.

Your Council, which has the ultimate responsibility for the conduct of the Institution's affairs, has held four meetings during the year. The greater part of the Institution's work is conducted through our various committees. The principal function of the Council is to review the work of its committees and to issue fresh guidance on matters of policy and practice.

The opportunity is taken at each Council meeting to discuss some major point of Institution policy in order to ensure that our progress is kept continually under review. As much of the work of the Council comes within the purview of one or another of the Committees, I will follow the practice of my predecessors in office by dividing this report into various sections.

Production Exhibition and Conference

The second Production Exhibition and Conference was held at Olympia from May 23rd — 31st, 1956. Following the lead given to the country by the former Chancellor of the Exchequer, Mr. R. A. Butler, the theme chosen for the Conference was "Investing in Success". A series of Papers was presented by leading authorities, each one taking as his title Investment in one or another of the factors which contribute to success. The full proceedings have already been published in the Institution's Journal, so I will not comment further upon them.

The general impression was that the Exhibition did not make the same force of impact as the first one. There were a number of factors which contributed to this impression. In the first place, although there were more exhibits this time, the Exhibition was staged in a much larger hall and one therefore gained the impression that there were far fewer exhibits. However, I think the main criticism of the Exhibition was not in the quality of the exhibits or in their number; indeed, all who visited the Exhibition agreed on the immense amount of interest which was there. The real point of criticism was that there were too many static displays and it was inevitable that the exhibitors who had some movement on their stands attracted far more interest.

The Exhibition and Conference again attracted interest from H.M. Government. The opening of the Exhibition and Conference was performed by The Rt. Hon. Iain Macleod, M.P., Minister of Labour and National Service, and a number of other members of the Government visited the Exhibition during its course. A considerable number of visitors from foreign countries attended the Exhibition, notable amongst them being a party of 100 production engineers from France, who spent two days making a very close study of the Exhibition.

Your Council feel that this Exhibition is a very important contribution to our industrial life. It provides a unique opportunity for industrial organisations to show how their productivity has been improved by the application of the results of research and development. It is the one occasion when the work of the production engineer can be demonstrated in its best form, free of the atmosphere of salesmanship. Most of the stands were manned by technical experts, production engineers and their scientific colleagues. Many managements commented with surprise that they found that these "back room boys" made excellent ambassadors for their companies.

Your Council have decided to sponsor the third Exhibition, which will be held at Olympia in 1958, and again to promote a Conference concurrently with the Exhibition. The experience which has been gained in the first two Exhibitions will be embodied in this third Exhibition and will be expressed in terms of a new lay-out and method of presentation.

I should like to thank Mrs. M. A. Montgomery and

her co-Directors of Andry Montgomery Ltd., the organisers of the Exhibition, for their very close co-operation in this important venture. I should also like to record the Institution's appreciation of the services of the members of the Conference Organising Committee, who devoted many hours of their spare time to ensure the success of the occasion. The Committee was under the Chairmanship of Sir Walter Puckey.

Regional and Section Activities

The strength of our Institution has always stemmed from the fact that by far the greater proportion of our activities are conducted in the Regions and local Sections. On the 30th June, 1956, there were 38 senior Sections in the U.K. and 12 Graduate Sections. All these Sections were grouped into 12 Regions. In addition, there were eight Sections in countries outside the U.K. During the year a new Graduate Section was formed in Rochester and the first Graduate Section to be established outside the U.K. was formed in Melbourne.

(a) *Sections in the U.K.*

The earlier difficulties which we experienced in operating our Regional Organisation are now being overcome. Over 300 lecture meetings were held in our Sections in the U.K. during the year. In addition, many enjoyable social functions have been arranged. Not the least interesting part of our activities in the Sections are the many varied works visits which are arranged. I believe that this is a feature of our activities which should be developed much more than it is, as in my opinion regular visits to other factories are very stimulating to production engineers.

Several Conferences have been organised during the year in our Regions and Sections. The Southern Section again organised a Conference on "Problems of Aircraft Production" in January, 1956. Although this Conference is organised by the Southern Section and is held in the University of Southampton, it has now become established as a national event and one of the most important in the aeronautical calendar. The Conference room was filled to capacity and, indeed, a number of applications for tickets had to be declined.

The Midlands Region held a Conference on the 16th May, 1956, at the Works of the Austin Motor Company Limited. Sir Leonard Lord, the President, was host to over 400 members of the Institution from all Sections in the Midlands Region.

The North Midlands Region held a one-day Conference on "Aspects of Automation" at Peterborough on the 1st June, 1956.

The London Graduate Section and the Halifax Graduate Section both organised Week-End Schools which proved to be very enjoyable and instructive occasions.

The Annual Graduates' Representatives Conference was organised this year by the Liverpool Graduate Section and the theme of the Conference was "Education and the Production Engineer".

The Annual Conference of Regional and Section Hon. Secretaries was held at Headquarters in May. There were some very useful discussions on matters affecting Institution administration.

(b) *Sections Outside the U.K.*

As Vice-Chairman of Council during the year under review, it was my privilege to act as liaison between the Council of the Institution in London and the Councils and Sections of the Institution outside the U.K. In this capacity I have had an interesting and enjoyable correspondence with our colleagues in other countries. I feel that this liaison is a most valuable one, as it enables the Council in London to keep in close touch with members throughout the Institution.

My correspondence has shown that the most difficult problem that our Councils and Sections outside the U.K. have to deal with is the question of applications for membership. Some views have been expressed that the present regulations for membership are too rigid ; that in raising the standard of membership the Council have perhaps become too formal in their approach. On the other hand, there is the strongest possible pressure from all sections of the membership that the Institution should become firmly established as a professional body on a par with the other senior engineering institutions. The fact must be faced that however desirable it may be from time to time to admit certain individuals to membership, unless the Institution maintains the highest standards of academic qualifications, true professional status will remain beyond our reach. Your Council has spent many hours debating this most difficult problem. Undoubtedly, without changing the regulations in any way, there is room for some flexibility and your Membership Committee have been asked to prepare a report on the subject for the Council to consider during the coming year.

Visitors. It is always a source of pleasure to us to receive visits from our members who reside in distant parts of the world. We have had a steady flow of such visitors during the year and they have had many useful conversations with the Secretary and other senior members of the staff. Several members of Councils and Sections outside the U.K. have had the opportunity of attending Council meetings at Headquarters during their stay in this country. We had the pleasure of a most interesting visit from Mr. R. A. P. Misra, the Chairman of the Bombay Section.

Several members from the U.K. have also visited various parts of the Commonwealth. The President, Sir Leonard Lord, was Guest of Honour at a Luncheon given for him by the Australian Council. The Luncheon was held in Sydney. This is the first occasion when a President in office has been able to visit any of the Institution Sections outside the U.K.

Finance

Reviewing a half-year's experience at the end of December, 1955, we found that our expenditure was very closely related to our budget and our confidence

that our finances were well under control were justified. Then came the blow. In the New Year the Postmaster General announced changes in postage and telephone charges: overnight the cost of posting our Journal to the members was doubled. The Secretary calculated that the changes in the postal and telephone charges would cost the Institution between £4,000 - £5,000 extra per annum. We were thus faced with the immediate certainty of a deficit on the home accounts in the year under review, when the increased charges would operate for a period of about five months, and a very much larger deficit in a full year. We were forced to the conclusion that there was no way of avoiding an increase in the membership subscriptions. Simultaneously our kindred institutions had been forced by the same circumstances to this conclusion.

In debating the amount of the increased subscription, two views were advanced. One view was that since inflation was continuing, it would be better to make a substantial increase in subscriptions which would provide for the future a long way ahead and avoid the possibility of going to the membership for a further increase in a few years' time. The contrary view was that this kind of counter-inflationary budgeting, when projected throughout the country, was in fact the cause of inflation. and that the Institution should call for an increase in subscriptions which would meet our immediate demands and provide only a small margin for the future. This view prevailed, with a result that it was proposed that subscriptions should be increased by 21s. per annum in the U.K. and 10s. 6d. per annum for those members residing outside the U.K.

The increase in membership subscriptions was received throughout the U.K. almost without comment. The situation was accepted as inevitable.

The accounts are published in full on pages 66/68 and I would like to take this opportunity of directing your attention to one or two points.

It is gratifying to see that our income from membership subscriptions shows an increase over the previous year. You will notice that the item "Recovery of Income Tax on Subscriptions" of £2,283 appears to be only about a half of the amount recovered in the previous year. This is simply due to the fact that owing to an incidence of dates in the previous year, we were credited for two years' recovery in one year.

The receipts from our Journal show a substantial increase. The Editorial Committee have done splendid work for the Institution in increasing the income of the Journal to an extent which offsets the steadily increasing costs of production, which are shown on the opposite side of the account.

Our total income of £79,060 shows an appreciable increase over the former year at £72,882.

Looking at our expenditure under the headings of "Establishment Charges", "Administration" and "Salaries", the modest increases not only reflect the continual inflationary pressure but also a measure of our expanding activities.

The most significant increase in expenditure comes under the heading "Journal", where you will see that the Journal for the year cost us more than £6,000 over the previous year. The increase has been directly caused by rising costs. Later on in the report, in commenting upon the work of our Editorial Committee, I will mention the steps which this Committee have taken to combat this contingency.

You will observe a substantial charge for the production of the Year Book. It had been our intention to publish the Year Book as a regular feature and so part of the initial cost of setting the type had been carried forward. Your Finance and General Purposes Committee came to the conclusion, however, that publication of the Year Book as an annual feature could not be justified under present circumstances and it was therefore decided to cease publication for the time being and to meet the accrued charges.

The Income and Expenditure Account, of course, includes not only the U.K. but also the figures for our Councils and Sections outside the U.K. and the net result of our year's working is an excess of income over expenditure of £843.

The summary of the Income and Expenditure Account published on page 67 shows how the figures are divided between the U.K. and the Councils and Sections outside the U.K. It will be seen that on the home account we sustained a deficit of £246. This deficit can be attributed entirely to the increased postal charges. Indeed, but for the most vigorous efforts at our Headquarters to keep all items of expenditure under the most rigid control, this deficit might have been substantially higher. Undoubtedly, if we had not increased our subscriptions at the end of the year we should have faced a deficit of the order of £5,000 - £6,000 at the end of the present year, a state of affairs which obviously could not have been allowed to continue.

The Balance Sheet sets out the state of our assets and liabilities: the proportion in the U.K. and outside the U.K. are shown in the next analysis. A comparison of the figures with the previous year shows a modest improvement in our position.

The adoption of the accounts is the subject of a special item on the Agenda and you will then have an opportunity to ask questions or to make comments.

Production Engineering Research Association

During the year we have taken steps to strengthen our liaison with the Production Engineering Research Association and we have arranged a number of reciprocal facilities between our two institutions. Most of these concern the administration and have been designed to provide several points of contact between both organisations.

An important development is the establishment of P.E.R.A. Scholarships. P.E.R.A. admits each year a limited number of student engineers who are given a course of six months' training in the P.E.R.A. Laboratories. Hitherto, these student engineers have been confined to firms who are subscribing members of P.E.R.A., but the P.E.R.A. Council have now agreed that the Institution may nominate a limited number of young engineers for scholarships at P.E.R.A. who are not employed in P.E.R.A. member firms. It is

proposed also to arrange for visits to P.E.R.A. of members of the Institution on a Regional basis. These visits will start next year when the large new laboratories at P.E.R.A. are opened.

Education and Membership Committees

"Broadening of the Base"

The Education Committee have been working hard during the year on proposals to modify the Institution's examination structure so as to give effect to the policy of "Broadening the Base". At the moment the Institution's examination is confined almost entirely to mechanical engineering applications in metal working industries. It is recognised, however, that there are many production engineers engaged in other industries and the purpose of the proposed changes is to make it possible for these production engineers to become members of the Institution.

Summer School

The Summer School was again held at Ashorne Hill, near Leamington Spa, from 25th - 28th August, 1955. The theme for the Summer School was "Education for Production Management". More than 90 visitors and members attended.

Delft Conference

With one or two notable exceptions, the universities in the U.K. make no provision for education for production engineering. The university authorities have steadfastly declined to recognise production engineering as being suitable for work at university level. On the other hand, many of the leading universities in Europe have Faculties or Schools of Production Engineering, some of them having been in existence for upwards of 50 years.

Your Education Committee, therefore, decided to organise a small conference in Europe to provide an opportunity for representatives in the U.K. to discuss the teaching of production engineering in universities with a number of professors from European universities. The Conference was held in Delft on the 25th and 26th April, 1956. The members of the Conference were :-

U.K. Delegation. Mr. G. R. Pryor, leader of the Delegation ; Mr. F. W. Cooper ; Mr. J. France ; Prof. H. Wright Baker ; Prof. A. F. Burstall ; Prof. O. A. Saunders ; Dr. N. A. Dudley ; Dr. F. Koenigsberger ; Dr. N. Gross, Imperial College, London University.

Netherlands Delegation. Prof. J. Landberg, Mechanical Engineering Dept., Delft University ; Prof. R. van Hasselt, Mechanical Engineering Dept., Delft University ; Prof. T. J. Bezemer, Secretary General, Inter-University Contact, (I.U.C.), Delft ; Prof. Verhagen, Technological University, Delft ; Dr. B. J. in den Bosch, Executive Secretary, (I.U.C.), Delft.

Belgium Delegate. Prof. Herpol, Ghent University.

Switzerland Delegate. Prof. E. Bickel, Zurich University.

Western Germany Delegate. Prof. J. Mathieu, Aachen University.

The meeting proved to be a most valuable one : extensive conversations took place. A full report of this Conference has been published *. Obviously, this first Conference could only be exploratory but I very much hope that it will be followed by a much larger Conference in the U.K., when these talks can be considerably extended.

Higher Technological Education

The publication of the Government White Paper on "Higher Technological Education" in February, 1956, was received with very great interest by the Education Committee. A special Committee, known as the National Council for Higher Technological Awards, was set up by the Ministry of Education, under the Chairmanship of Lord Hives. This Council (which is frequently referred to as The Hives Council) has established two Boards of Studies — one for Engineering and the other for Technologies other than Engineering. The Institution was asked to appoint a representative to serve on the Board of Engineering Studies and Sir Walter Puckey was nominated. Sir Walter has since been elected Chairman of the Board of Engineering Studies and a member of the Hives Council.

The Council is proposing to establish two national awards ; one to be known as the Diploma in Engineering (Dip.Eng.), and the other, the Diploma in Technology (Dip.Tech.). Courses of study leading to these awards will be established in the major technical colleges and it is hoped that the awards will carry the same academic status as a university degree. This is a very significant proposal and brings the U.K. much nearer to well established practice in European countries.

Associate Membership Examination

The examination was set in May, 1956. A total of 229 candidates sat the examination, which was slightly less than in the previous year. Approximately 25% of the candidates were successful in passing the examination.

Membership

It is gratifying to be able to report a continuing increase in our total membership. The figures below show a net increase over the year of 441.

	30th June, 1956	30th June, 1955
Honorary Members	8	8
Members	1,685	1,593
Associate Members	4,979	4,875
Associates	158	156
Graduates	2,230	2,125
Students	1,248	1,125
Affiliated Firms	234	219
	10,542	10,101

* In the December, 1956, Journal.

During the year the Chairman of the Membership Committee was Mr. F. Woodifield and the Chairman of the Education Committee was Mr. R. Ratcliffe. Both Mr. Woodifield and Mr. Ratcliffe have been re-elected as Chairmen for the current year.

Hazleton Memorial Library

There has been an interesting change in the pattern of use of the Library during the past 12 months. Whilst there has been only a small increase in the number of requests to borrow books or periodicals, there has been a very large increase in the number of technical enquiries, calling for a certain amount of research in the Library. The Institution's Conference on "The Automatic Factory—What Does it Mean?", held at Margate in June, 1955, brought an enormous number of enquiries in to the Library. The Librarian reports a continuing increase in the number of enquiries received from other libraries and professional organisations, which is an indication of the growing reputation of our Library. The majority of the enquiries received are straightforward requests for information or for books, but an increasing number are in the form of requests for advice on specific technical and production problems. Whilst the Library does not contain all the information necessary to answer these many enquiries, it maintains numerous channels of communication with other specialist organisations and with members of our Institution, which makes it possible to provide authoritative answers to most of the enquiries.

The publication of the Library Catalogue in November, 1955, has proved to be very worthwhile. The edition has now been exhausted and the demand indicates that a new edition will be necessary very soon.

The Chairman of the Library Committee during the year was Lord Sempill and he has asked me to take this opportunity of expressing his appreciation to all those members of the Institution who have helped the Library Committee by reviewing new books and in other ways.

Editorial Committee

The Editorial Committee have been faced with some very difficult problems during the year. The unending pressure of rising costs has made the economic production of the Journal no easy task. The Journal has increased in size during the year, the average number of editorial pages being 79 as compared with 65 in the previous year. The average number of advertising pages has increased to 98 as compared with 85 in the previous year, and the charges for advertisements have been increased. However, the heavy increase in postage rates is a severe blow which it will be impossible completely to off-set by increasing charges.

The larger Journal has made it necessary to post it in an envelope instead of a wrapper, which again has meant an additional cost. The difficulty is to find an envelope which is strong enough to carry the Journal and yet not prohibitively expensive.

Both the advertising and editorial sections of the Journal are now being printed on less expensive paper as a contribution towards economy.

The Journal has fully maintained its wide circulation during the year and is now regarded as being one of the most important of the technical publications. The larger Journal naturally carries a good deal more editorial information. Your Editorial Committee have always pursued the policy of publishing Papers of wide general interest rather than catering for the very narrow interests of highly advanced technical specialists. The numerous comments which are received from members indicate that this policy is much appreciated.

The Chairman of the Committee during the year was Mr. M. Seaman.

Papers Committee

The Papers Committee's main purpose is to obtain more and better Papers. The Committee are very strongly of the opinion that there is a vast source of talent within the membership of the Institution which has not been tapped and the Chairman of the Papers Committee has requested Regional and Section Chairmen to make every effort to persuade members to prepare Papers for the Institution. It should be the ambition of every young production engineer to present at least one Paper to his profession. It is a criticism of engineers that they are modest about their attainments and regard a Paper as being beyond their powers. It is true that one of the weaknesses of the education of engineers is that they are not well trained in the art of self-expression, but the fear that they might not be able to express themselves in the most polished English should not be a deterrent to the author of a Paper. Headquarters staff are more than willing to help with editing.

The 1955 *Viscount Nuffield Paper* was presented at the Royal Institution on 15th December, 1955, by Dr. G. H. Daniel, Under Secretary of the Ministry of Fuel and Power. Dr. Daniel chose as his subject: "Britain's Energy Prospects" and his Paper gave a very penetrating analysis of our fuel and power requirements for a very long time ahead. The full text of the Paper was printed in the February, 1956, Journal.

The 1955 *Sir Alfred Herbert Paper* was presented at the Royal Institution on the 9th February, 1956, by Dr. N. H. Mackworth, Director of the Applied Psychology Research Unit of the Medical Research Council, Cambridge. Dr. Mackworth's subject was: "Work Design and Training for Future Industrial Skills". This Paper promoted a most lively discussion. The full text of the Paper was printed in the April, 1956, Journal.

The 1955 *George Bray Memorial Lecture* was presented at the Royal Institution on 7th March, 1956, by Sir Gordon Russell, C.B.E., M.C., R.D.I., Director of the Council of Industrial Design. Sir Gordon's subject was: "Pride in Workmanship: Today's Challenge". The full text of the Paper was printed in the May, 1956, Journal.

The Lord Sempill Paper, which was inaugurated in the year to mark the long association of Lord Sempill with the Institution and with aeronautics, was presented by Sir Roy Fedden, M.B.E., at the Conference on "Problems of Aircraft Production" at the University of Southampton on 6th January, 1956. Sir Roy's Paper, "Britain's Aircraft Needs", promoted world-wide interest.

The Chairman of the Papers Committee during the year was Mr. K. J. Hume.

Standards Committee

The Standards Committee have continued the routine work of commenting on draft British Standard Specifications and nominating Institution representatives to serve on British Standards Institution Technical Committees.

The Committee have been concerned at the divergence of practice in cutting tool nomenclature and addressed an enquiry on the subject to affiliated firms. The result of the enquiry showed a marked desire for a revision of British Standard 1866 and a recommendation has now been sent to the British Standards Institution that this Standard should be revised.

The considerable expansion in the Institution's technical work, not only through the Standards Committee but also through other Committees, is making it more and more imperative that there should be an easy route of access between individual members of the Institution and Headquarters. The Institution frequently needs the advice and guidance of an expert on some particular problem and, whilst it is well known that such experts are within the membership of this Institution, it is sometimes extremely difficult to locate them. Accordingly, the Standards Committee have considered in great detail a revision of our records system. The Committee are particularly grateful to Mr. E. G. Brisch, a member of the Committee, who has devised a new classification system. This system will be put into use as soon as funds and additional staff become available.

The Standards Committee, with the British Standards Institution, were responsible for organising the second Annual Conference of Standards Engineers which was held in May, 1956, at Standards House, the Headquarters of the British Standards Institution. A Joint Advisory Committee has now been set up by the Institution and the British Standards Institution to organise future Conferences and to provide a liaison between the Institution and the British Standards Institution on all matters of standardisation policy. Another Conference of Standards Engineers is being planned for May, 1957.

Two sub-committees have been set up during the year: one on International Standardisation, under the Chairmanship of Mr. T. A. C. Sparling, and the other on Unit Heads and Platens, under the Chairmanship of Mr. J. A. W. Styles.

The Chairman of the Standards Committee during the year was Mr. R. E. Mills.

Research Committee

The Research Committee and their sub-committees have been extremely active during the year. Following a recommendation from the Finance and General Purposes Committee, a Working Group on Materials Handling was formed under the Chairmanship of Mr. A. G. Hayek to investigate the possibility of preparing a syllabus and an examination on Materials Handling and to make recommendations. The Working Group have now produced a report which is being studied by the Research Committee and the Education and Membership Committees.

The Materials Handling Sub-Committee are also producing a series of case studies on Handling which are being published each month in the Journal.

The Sub-Committee organised in Birmingham, in March, 1956, a film and discussion evening devoted to Materials Handling, which was attended by over 400 members and visitors. As a result of this, the Materials Handling Sub-Committee have been asked by a number of Sections to organise similar film and discussion evenings in other parts of the country, and arrangements are being made accordingly.

Following the publication of the report on "Material Utilisation in the Metalworking Industry", the Material Utilisation Sub-Committee was reconstituted under the Chairmanship of Mr. R. N. Marland. This Sub-Committee is now investigating the use of raw and process materials in the engineering and allied industries. Four panels have been set up to deal with each of the fields specified. An article, describing the work of the Sub-Committee, was published in the October, 1956, Journal.

With the publication of their report on "Production Control and Related Works Statistics", which was published with the Institute of Cost and Works Accountants, the work of the Production Control Sub-Committee was completed. The report was very well received and promoted considerable interest. The Chairman of the Sub-Committee was Mr. F. G. S. English.

The Sources of Information Sub-Committee have been working hard on a Directory of Sources of Information for the Production Engineer. This work is now in a very well advanced stage and it is hoped that publication will take place in the coming year. The Chairman of the Sub-Committee was Mr. Peter Spear.

A new Sub-Committee on Control of Quality has been set up under the Chairmanship of Mr. R. K. Grunau.

The Joint Committee for the Measurement of Productivity, which has existed for a number of years between the Institution and the Institute of Cost and Works Accountants, has now been reconstituted and is now known as the Joint Research Committee. The Committee has representatives from both our own Institution and the Institute of Cost and Works Accountants, under the Chairmanship of Mr. B. H. Dyson. This very valuable Committee provides for permanent liaison between the two institutions where their work overlaps. The Joint Research Committee has now set up two sub-committees: one to investigate Electronics and Kindred Modern Developments as Applied to Process Loading, under the Chairmanship of Mr. C. E. Sutton of the I.C.W.A.; and the other

to investigate Efficient Utilisation of Capital in Industry, under the Chairmanship of Mr. B. G. L. Jackman, M.I.Prod.E.

The Research Committee find that their work is very much hampered by the lack of a full-time Technical Officer on Headquarters staff and they have been pressing for this appointment to be made. It is possible that an appointment may be made in the coming year.

There has been a proposal before the Research Committee that they should set up a special sub-committee to examine Human Relations in Industry. The Research Committee, however, have come to the conclusion that Human Relations are inseparable from the problems of the production engineer and that each sub-committee, in its investigations, should consider Human Relations as an essential part of its programme.

Mr. B. H. Dyson was Chairman of the Research Committee during the year. Mr. Dyson has been associated with the work of the Research Committee for a very long time and his tremendous energy and knowledge have been reflected in the work of the Committee throughout the whole of this period. I should like here to place on record, on behalf of the Research Committee, our appreciation of Mr. Dyson's service to the Institution.

Honours

It is with very great pleasure that the Institution has noted that the following members have been honoured by Her Majesty the Queen during the year :-

Knight Bachelor

G. H. Dowty.

K.B.E.

Sir Claude Gibb.

C.B.E.

R. M. Currie ; J. H. Larrard.

O.B.E.

J. N. Kirby ; F. H. Perkins.

M.B.E.

A. L. Beech ; A. W. Payne ; A. H. Selby.

I am sure that all will join with me in congratulating these members on Her Majesty's recognition of their services to the country.

Obituary

It is with regret that the death of 45 members during the year must be recorded. Their names have been published in the Journal.

Awards

On the recommendation of the Papers Committee, the following awards for Papers were made during the year :-

Institution Medal for the Best Paper presented to a Section by a Member : To Mr. R. N. Marland for his Paper entitled "A Job Evaluated Wages Structure".

Institution Medal for the Best Paper presented to a Section by a non-member : To Mr. J. A. Stokes and Mr. N. Milne for their Paper entitled "Electronics as an Aid to Production".

The Hutchinson Memorial Award (for the Best Paper presented to a Section by a Graduate) : No award made this year.

The Lord Austin Prize (for the Best Essay by a Graduate) : To Mr. S. A. Onions for his essay entitled "Welding Distortion Problems Encountered in the Gas Turbine Industry".

Schofield Travel Scholarship : Awarded to Mr. H. Scholes.

Services of Members

I find myself in complete agreement with the remarks on this subject which my predecessors in office have made in former years. Without the services of its members, the Institution could not carry on its work. It is very gratifying to me to be able to report that during the past year at any given moment more than 10% of the total membership was engaged on some task or another on behalf of the Institution. Members give their services to the Institution in a variety of ways : they serve on the Council and on Committees ; they represent the Institution in the work of other organisations ; they serve as governors of technical colleges, as members of engineering advisory councils ; they assist the Standards Committee in commenting on draft specifications and by making proposals for new Standards ; they help the Library Committee by reviewing or abstracting new books and periodicals ; and in many other ways too numerous to mention.

I should like here to place on record the Institution's appreciation of all this invaluable service so freely given. The Institution provides a most valuable medium for public service : it is much more than a professional organisation established merely to regulate the conduct of its members. It has a clearly defined duty to contribute to our social well-being by improving standards of productivity in our manufacturing enterprises. Such work can bring much satisfaction ; any member who feels he would like to serve the Institution and, thus the community at large, in this way should get in touch either with his local Honorary Secretary or with the Secretary at Headquarters.

Headquarters Staff

During the year under review, no major changes have occurred and, in an expanding Institution such as ours, it is inevitable that administration is always a step behind the rate of expansion. Correspondingly, Headquarters staff are under continual pressure and they all work very hard indeed.

The fact that our Headquarters is located in Mayfair does mean that we are always faced with keen competition for staff from business houses, who tend to attract personnel by higher salary levels and amenities, which in fact are beyond the range of the Institution. Amongst the junior ranks of the staff, I am afraid we must always be prepared to face up to changes.

Without making reference to any particular members of the staff, I am sure it would not be your wish to allow this Annual General Meeting to pass without

recording our appreciation to Mr. Woodford and his colleagues for their many years of loyal service to the Institution.

The Future

What does the future hold in store for production engineers ? The phenomenal rate of technological change over the past decade or two is surely changing the pattern of British industry ? One wonders what sort of production engineers industry will be requiring in, let us say, 20 years' time. It seems to me that there are immense possibilities and the production engineer has a serious responsibility to examine and look into the future and try, so far as he is able to do so through his own organisation, to anticipate and provide for the needs of industry in the years ahead. These problems are not only technological : changes in technology produce changes in human relations ; new stresses are set up, old problems disappear. The human factor in production is of the utmost importance and one which no responsible production engineer can overlook. In presenting this report, I commend to you all the opportunities for service which the Institution offers.

Hazleton Memorial Library

REVIEWS

Members are reminded that copies of the Library Catalogue may be obtained from the Librarian, price 2/6d., plus 4d. postage (price to non-members, 10/-, plus 4d. postage).

" Brazing Manual." American Welding Society, New York. *New York, Reinhold; London, Chapman & Hall,* 1955. 193 *pages. Illustrated. Diagrams. Table.* 38s.

There has long been a need for a comprehensive reference book on brazing and, as often happens, two books were published at approximately the same time. Although this book is well written with a fair balance between theory and practice, in the reviewer's opinion it has been over-condensed and does not come up to the standard of its British equivalent.

The opening chapters give a sketchy introduction to processes, equipment and properties of base metals, with which most engineers in this field will be familiar. These are followed by well prepared and interesting chapters on filler metals, fluxes and atmosphere, and joint design. There are interesting sections in some detail on each of the commonly used base metals including nickel and high nickel alloys and somewhat shorter sections on precious metals, hard carbides, tungsten, molybdenum, zirconium, etc. The book is well illustrated with drawings and photographs and there is a useful appendix giving the properties of brazable metals and alloys in tabular form. G.C.S.

" Swiss-Type Automatics " by G. A. W. Morgan. *London, Machinery Publishing Co.,* 1956. 3 *volumes* — 66 *pages,* 58 *pages and* 50 *pages. Illustrated. Diagrams.* (Machinery's Yellow Back Series, 36, 36a, 36b.)

I admit that I did not at first think that this work warranted a review, but was told that the Yellow Back Series was so popular amongst our members that, if only for that reason, volumes in the series should receive critical treatment in the Journal. Having studied these three little volumes, I can understand the popularity of the series, and think it worthwhile making some small criticisms.

Volume 1 describes by means of text, photographs and diagrams, the following types of Swiss Automatics: Bechler, Gibbs, Gorton, Petermann, Tavannes, Tornos and Wickman, arranged most usefully in alphabetical order, so that this section constitutes in effect a comprehensive and easily referred to catalogue of Swiss Automatics. The first chapters describe general principles of the machines and the way they produce details.

Volume 2 deals with attachments and their applications: single spindle drilling attachments; two and three spindle attachments; slotting, undercutting and taper attachments; and special devices. It ends (somewhat illogically in my opinion) with a chapter on layouts and cam design.

Volume 3 deals with cam layout and tool design, and covers points not previously dealt with. Detailed examples are given of knurled screws, controlled valve stem ; knurled bush ; arbor blank ; and piston blank.

The book is concisely written and covers each aspect of the subject adequately. It should be a really useful reference work to jig and tool planning and processing departments, although its usefulness as a reference work is, unfortunately, moderated by what was probably a publisher's requirement: that of producing three volumes of approximately equal size. This has resulted in some illogicality in the arrangement of materials. For instance, processing is covered in Volumes 1 and 3 ; cam layout and design in Volumes 2 and 3. So that if you want to study, say, cam design, it is necessary to have all three volumes by you.

There is one point about which I feel strongly: the dimensioning of components should not be altered from that originally given by the draughtsman. A properly dimensioned detail is drawn to suit the function of the component. Altering the dimensions to suit the machine is analogous to telling the designer that " A job will be done in a particular way regardless of its proposed purpose ". This leads to the know-how (*sic*) method of production, used by some manufacturers when they are forced back to the designer's original intentions in order to make the product work.

In spite of these criticisms, I recommend this work, because its subject matter is sound and it can be used with confidence. R.E.M.

THE BALANCE SHEET AND ACCOUNTS FOR THE YEAR ENDED 30th JUNE, 1956, APPEAR ON THE FOLLOWING PAGES.

THE INSTITUTION OF PRODUCTION ENGINEERS

BALANCE SHEET as at 30th June, 1956.

1955				
£	£		£	£
		Accumulated Funds and Surplus		
25,000		The Viscount Nuffield Gift ...	25,000	
500		The Lord Austin Prize Fund ...	500	
100		The Hutchinson Memorial Fund	100	
500		The George Bray Memorial Fund	500	
	26,100			26,100
	500	Renovations Reserve		1,000
		Life Subscriptions: *less* amount transferred to Income and		
	1,014	Expenditure Account ...		1,106
	17,738	Income and Expenditure Account		18,581
	45,352			46,787
	56	Melbourne Prize Account ...		60
	131	Schofield Scholarship		
		Work Study Symposium: South		
	85	Africa		—
		Current Liabilities		
12,055		Sundry Creditors	6,856	
		Subscriptions Received in		
466		Advance	467	
		Bank Overdraft: *less* Sections		
615		and Cash Balance	5,611	
	13,136			12,934
	£58,760			£59,781

1955				
£	£		£	£
		Fixed Assets		
35,000		Freehold Premises: at cost ...		35,000
		Freehold Premises: Cost of Alterations and Equipment, *less* Donations, Reserves, etc.		
		Balance at 1st July, 1955 ...	2,813	
		Add expenditure *less* receipts during year	581	
2,813				3,394
		Furniture, Fittings and Plant at the net amount standing in the Institution's books at		
		30th June, 1948	1,531	
		Additions	7,201	
			8,732	
		Less Depreciation to date ...	3,959	
4,853				4,773
		Fund Investments at cost: as scheduled (Market Value		
1,100		£945		1,100
	43,766			44,267
		Current Assets		
		Sundry Debtors, Deposits and		
12,897		Stocks	13,334	
		United Building Society —		
2097		Deposit (South Africa) ...	2,180	
	14,994			15,514
	£58,760			£59,781

E. W. HANCOCK, M.B.E., *President.*

H. G. GREGORY, *Chairman of Council and Finance Committee.*

W. F. S. WOODFORD, *Secretary.*

Report of the Auditors to the Members of The Institution of Production Engineers.

We have obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purposes of our audit. In our opinion proper books of account have been kept by the Institution so far as appears from our examination of those books. Audited Balance Sheets and Accounts have been received from each of the Councils and Sections outside the United Kingdom, and these have been incorporated in the above Balance Sheet and annexed Income and Expenditure Account. We have examined the above Balance Sheet and annexed Income and Expenditure Account which are in agreement with the books of account audited by us and the audited Accounts of the Councils and Sections outside the United Kingdom supplied to us. In our opinion and to the best of our information and according to the explanations given us the said Accounts give the information required by the Companies Act, 1948, in the manner so required and the Balance Sheet gives a true and fair view of the state of the Institution's affairs as at 30th June, 1956, and the Income and Expenditure Account gives a true and fair view of the excess of income over expenditure for the year ended on that date.

20 Bloomsbury Square,
London, W.C.1.

20th November, 1956.

GIBSON, APPLEBY & CO.,
Auditors,
Chartered Accountants.

INCOME AND EXPENDITURE ACCOUNT for the Year ended 30th June, 1956.

1955 £	1955 £		£	£	1955 £	1955 £		£	£
		To Establishment Charges					**By Subscriptions**		
971		Rates	969		30,292		Renewals and Arrears ...	31,978	
1,551		Light, Heat and Cleaning	1,392		341		Transfers	333	
246		Repairs and Renewals ...	653		957		New	1,085	
	2,768			3,014	4,309		Overseas	4,173	
		„ **Administration Expenses**			542		Entrance Fees	437	
1,993		Postage and Telephone ...	2,296				Registration and Miscellaneous Fees	964	
4,562		Printing and Stationery ...	4,271		689		Recovery of Income Tax on		
		Professional Charges and					Subscriptions	2,283	
122		Insurance	559		5,546				
200		Audit	200			42,676			41,253
		Travel, Entertaining and				136	„ **Interest**		154
		Meetings (other than				29,597	„ **Journal Receipts**		36,805
1,594		Sections)	2,120			10	„ **Sale of Proceedings**		603
43		Miscellaneous	75			432	„ **Conferences**		—
	8,514			9,521		31	„ **Miscellaneous Receipts** ...		108
	16,757	„ **Salaries**		18,940		—	„ **Summer School, 1955** ...		137
		„ **Section Expenses**				275	„ **Examinations**		160
1,977		United Kingdom	2,062						
2,301		Overseas (Audit Fees £77)	2,321						
1,351		Central Services	1,370						
	5,629			5,753					
		„ **Journal**							
26,975		Printing	30,840						
2,860		Postage and Envelopes ...	5,137						
209		Reporting	259						
	30,044			36,236					
	299	„ **Institution Papers**		313					
	223	„ **Hazleton Memorial Library**		406					
	—	„ **Schofield Scholarship** ...		319					
	113	„ **Donations and Subscriptions**		119					
	—	„ **Conferences**		679					
		„ **Miscellaneous**							
12		Annual Dinner, 1955 ...	73						
100		Year Book	1,049						
117		Summer School, 1954 ...	—						
105		Press Cuttings	214						
142		Bank Interest and Charges	405						
	476			1,741					
		„ **Provisions**							
		Depreciation — Furniture							
	762	and Fittings		836					
	500	„ **Renovation Reserve**		500					
		„ **Balance** — Excess of Income							
		over Expenditure carried							
	7,072	down		843					
	£73,157			£79,220		£73,157			£79,220

APPROPRIATION ACCOUNT

1955 £		£	1955 £		£
450	To Transfer to New Building Fund ...	—	10,652	By Balance at 1st July, 1955	17,738
17,738	„ Balance carried forward	18,581		„ Excess of Income over Expenditure	
			7,072	brought down	843
			464	„ Transfer from Special Reserve	—
£18,188		£18,581	£18,188		£18,581

INVESTMENTS AT COST, 30th JUNE, 1956.

	£	£
The Lord Austin Prize Fund		
£95 8s. 5d. 3½% War Stock	100	
£575 8s. 3d. London County 3% Consolidated Stock, 1920	400	
		500
The Hutchinson Memorial Fund		
£95 8s. 5d. 3½% War Stock		100
The George Bray Memorial Fund		
£775 0s. 9d. London County 3% Consolidated Stock, 1920		500
(Market Value £944 16s. 5d.)		£1,100

THE INSTITUTION OF PRODUCTION ENGINEERS

SUMMARY OF INCOME AND EXPENDITURE ACCOUNT

for the year to 30th June, 1956.

	£	£		£
Expenditure in the United Kingdom	76,038		Income in the United Kingdom	74,730
Less—Cash remitted by Councils and Sections outside the United Kingdom	1,062	74,976	Income in Councils and Sections outside the United Kingdom	4,490
Expenditure in Councils and Sections outside the United Kingdom	2,339			
Add—Cash remitted to the United Kingdom	1,062	3,401		
Excess of Income over Expenditure in Councils and Sections outside the United Kingdom ...	1,089			
Less—Excess of Expenditure over Income in the United Kingdom	246	843		
		£79,220		£79,220

ANALYSIS OF ASSETS AND LIABILITIES at 30th June, 1956.

	U.K. £	*Outside U.K.* £		*U.K.* £	*Outside U.K.* £
Accumulated Funds and Surplus	39,796	6,990	**Fixed Assets**		
			Freehold Premises	38,394	
Melbourne Prize Account—Australia		60	Furniture, Fittings and Plant	4,598	174
			Fund Investments	1,100	
Current Liabilities				44,092	174
Sundry Creditors	6,510	346	**Current Assets**		
Subscriptions received in advance	401	66	Sundry Debtors, Deposits and Stocks ...	13,254	80
Bank Overdraft—United Kingdom	10,639		Investments—South Africa		2,180
			Cash at Bank and in Transit		
			United Kingdom	—	—
			Australia		2,240
			Bombay		262
			Calcutta		989
			New Zealand		436
			South Africa		644
			Canada		457
	£57,346	£7,462		£57,346	£7,462

— continued from page 3

have intelligence test scores equal or superior to the men of the university group, and that 50% are within the same range as those who have gained a university degree). It may be that 1,000 is an underestimate and that 2,000 is a possible figure. In support of this one may quote that in 1955 the number of Higher National Certificate successes was about 8,000, and of these between 3,000 and 4,000 are likely to attain membership of a professional institution.

It would seem, therefore, that from each of the streams contributing to the sandwich courses we might expect *now* about 2,000 students, giving about 4,000 in all. In the future we might expect many more. How many more is difficult to assess, but even if none of the attempts to increase the numbers of boys and girls in the science sixth forms of schools succeeded, or we did not change our present arrangements in any way, the natural increase in the numbers in the population in the university entrance age-group would lead to an increase of about one-third over the next six years and of one-half by 1966. It would seem that this is neither enough nor sufficiently rapid to meet the national industrial needs, although it must be confessed that there is some lack of precision about the number of technologists industry requires now and will require in the future.

The White Paper on Technical Education pointed out that the present annual output from advanced courses in technical colleges in England and Wales is about 9,500 (1,000 science degrees, 500 degrees in technology, 8,000 Higher National Certificate or the like). It went on "The Government now proposes to raise the capacity of advanced courses as soon as possible from 9,500 to 15,000."

This means more buildings and more teachers! A vigorous attempt to provide more and better technical college buildings is being made; the supply of teachers presents problems which are of outstanding importance but cannot be discussed now. But assuming these difficulties are overcome, the expansion would allow technical colleges (and Colleges of Advanced Technology in particular) to make an effective contribution to the attainment of the aim suggested in the recent report on "Scientific and Engineering Manpower in Great Britain," namely, that over the next ten to fifteen years we should aim at an annual figure of "graduations" in pure and applied science of about 20,000, as compared with 10,000 today.

A Changing Educational Pattern

How many of these the technical colleges will be asked to provide depends on the expansion in the universities, but it does seem likely that over the next ten years the pattern of education in the technical colleges will change considerably and, in particular, large numbers of technologists will pass through sandwich courses. I have mentioned earlier a figure of 4,000 annually that could be achieved quickly; this could be doubled if we tackled the building programmes with energy and if more teachers were made available from the larger number of new graduates.

Of course, the increase in the number of students attending sandwich courses would inevitably lead to a decrease in the numbers attending Higher National Certificate courses, and consequently in the numbers attaining graduate status in this way, but this decrease should be more than offset by the factors which have been discussed already. As far as one can see the pattern of part-time day and evening classes will not change very much, but it is likely that attendance at part-time day classes will increase and that evening class numbers may well fall. It is necessary to emphasise, however, that in spite of the development of sandwich courses the Higher National Certificate and post-Higher National Certificate courses will be as important as ever, and must attract increasing numbers if our industrial needs, for technicians as well as technologists, are to be met.

Because of the very nature of the subject of this Conference I have been concerned throughout with numbers, but to avoid misunderstanding I must stress, before I close, that we must be equally concerned with quality. Indeed, one of the attractive features of the sandwich course schemes is that they will enable the technical college to provide an increased measure of the benefits of a full and rounded education impossible in schemes of part-time day and evening study. They will provide, it is hoped, not only a technological training but an education, which must influence for good industry in particular and society in general.

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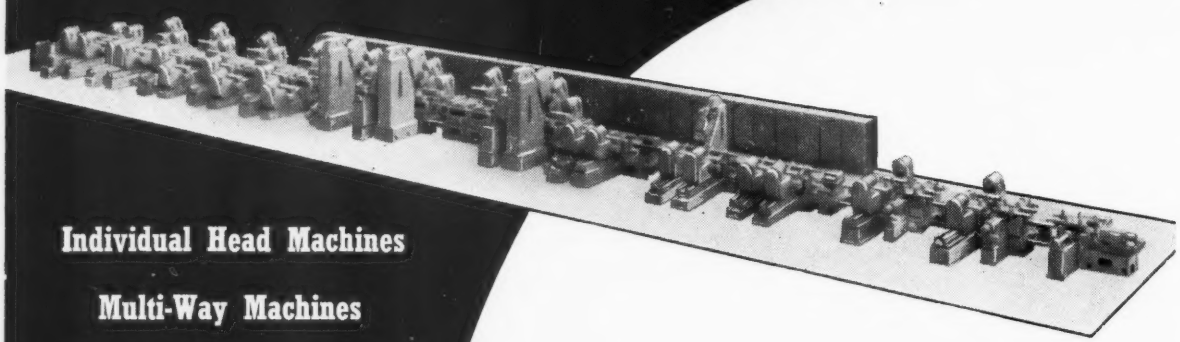

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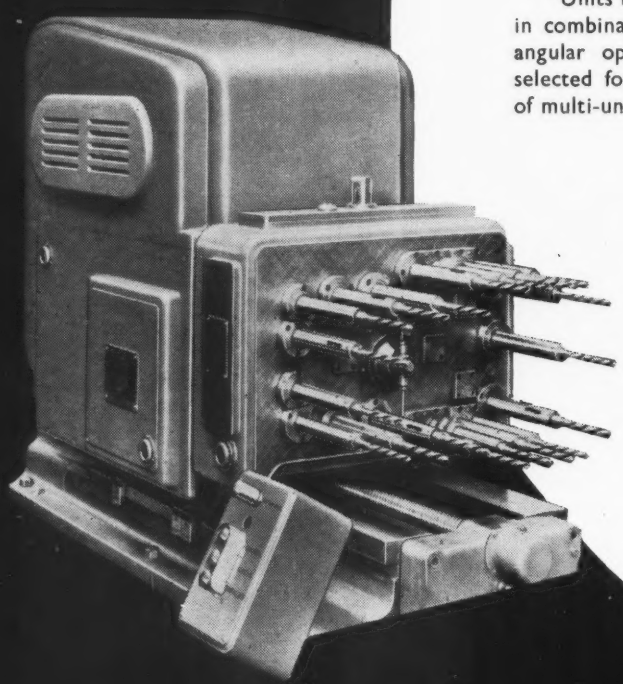

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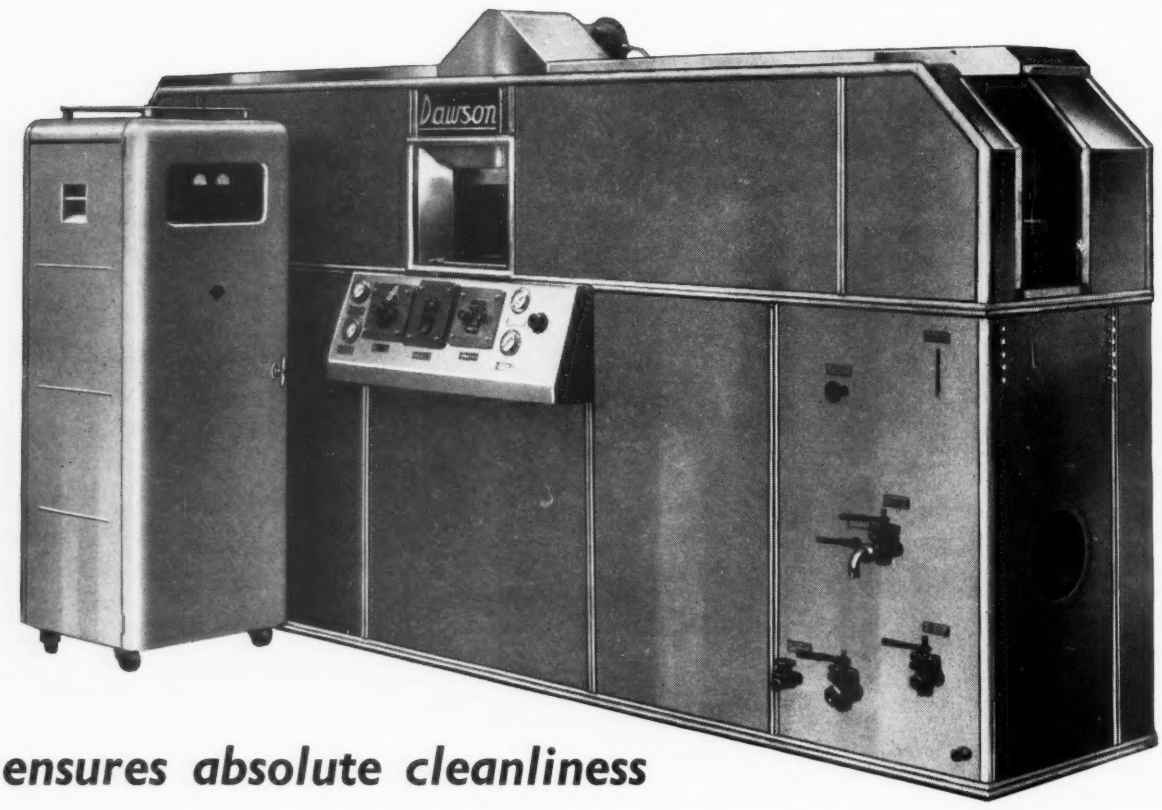

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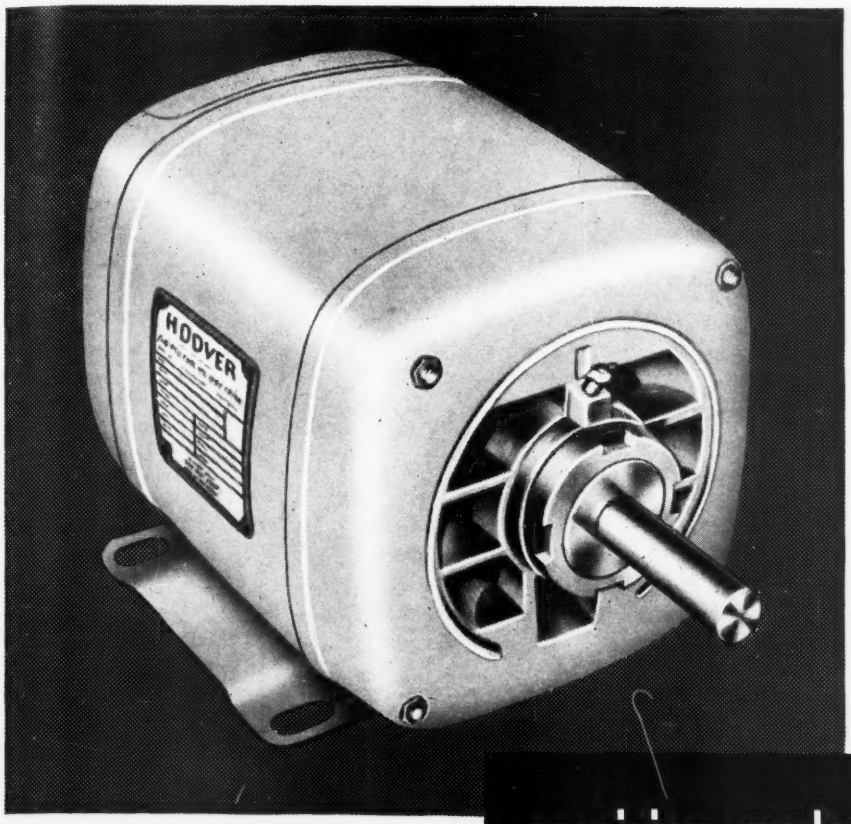

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Hoover F.H.P. Motors have won universal recognition in industry for power, precision and performance. Built around one basic design, incorporating all the latest engineering developments, this compact Hoover 'fractional' is quiet, free from vibration, and has an exceptionally effective cooling system. Competitive in price, all Hoover F.H.P. Motors are backed by the unique Hoover service plan. *For full technical information please write to:*

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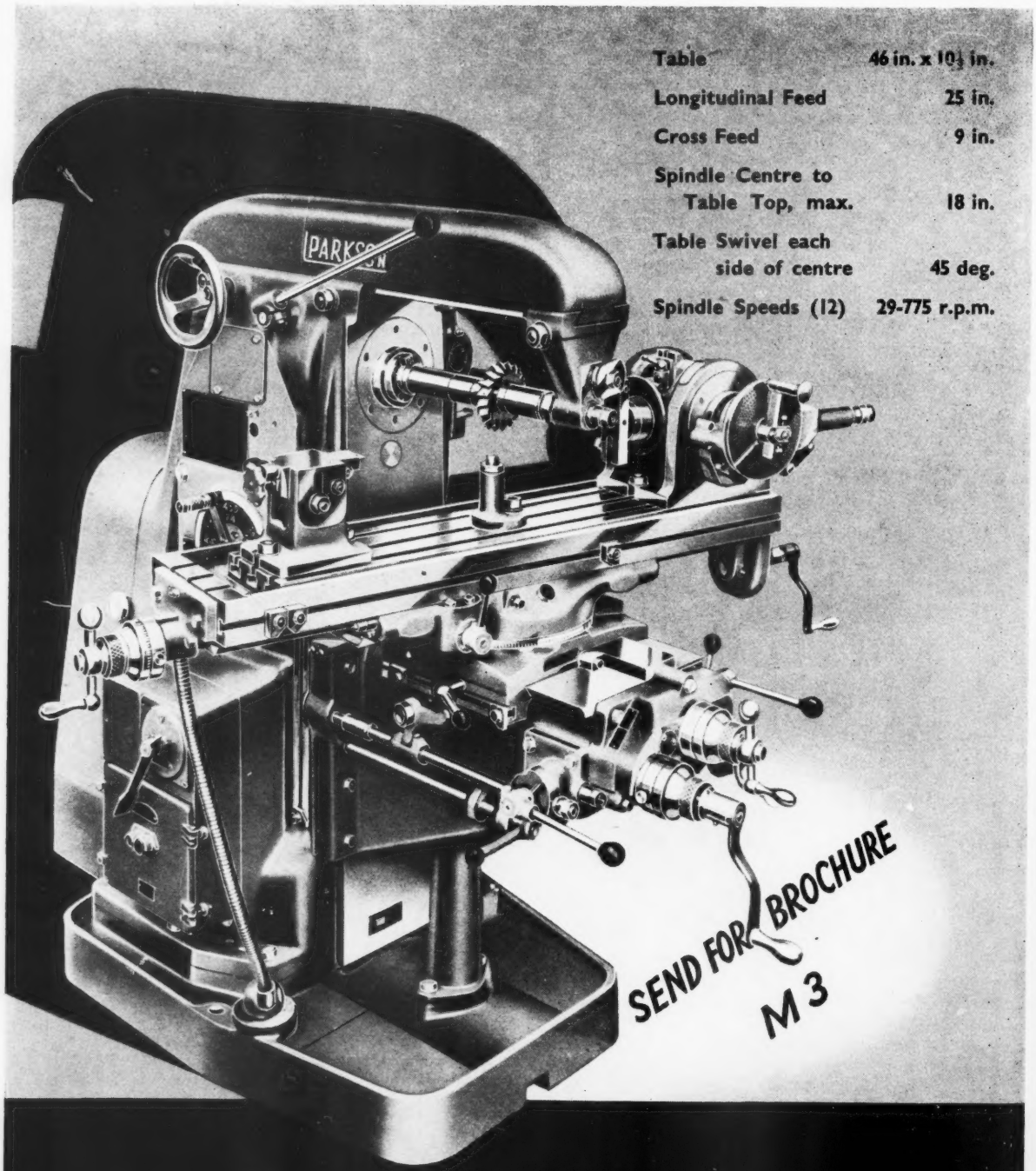
Table 46 in. x 10½ in.
Longitudinal Feed 25 in.
Cross Feed 9 in.
Spindle Centre to Table Top, max. 18 in.
Table Swivel each side of centre 45 deg.
Spindle Speeds (12) 29-775 r.p.m.
SEND FOR BROCHURE M 3

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UNIVERSAL MILLER

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SHIPLEY YORKSHIRE
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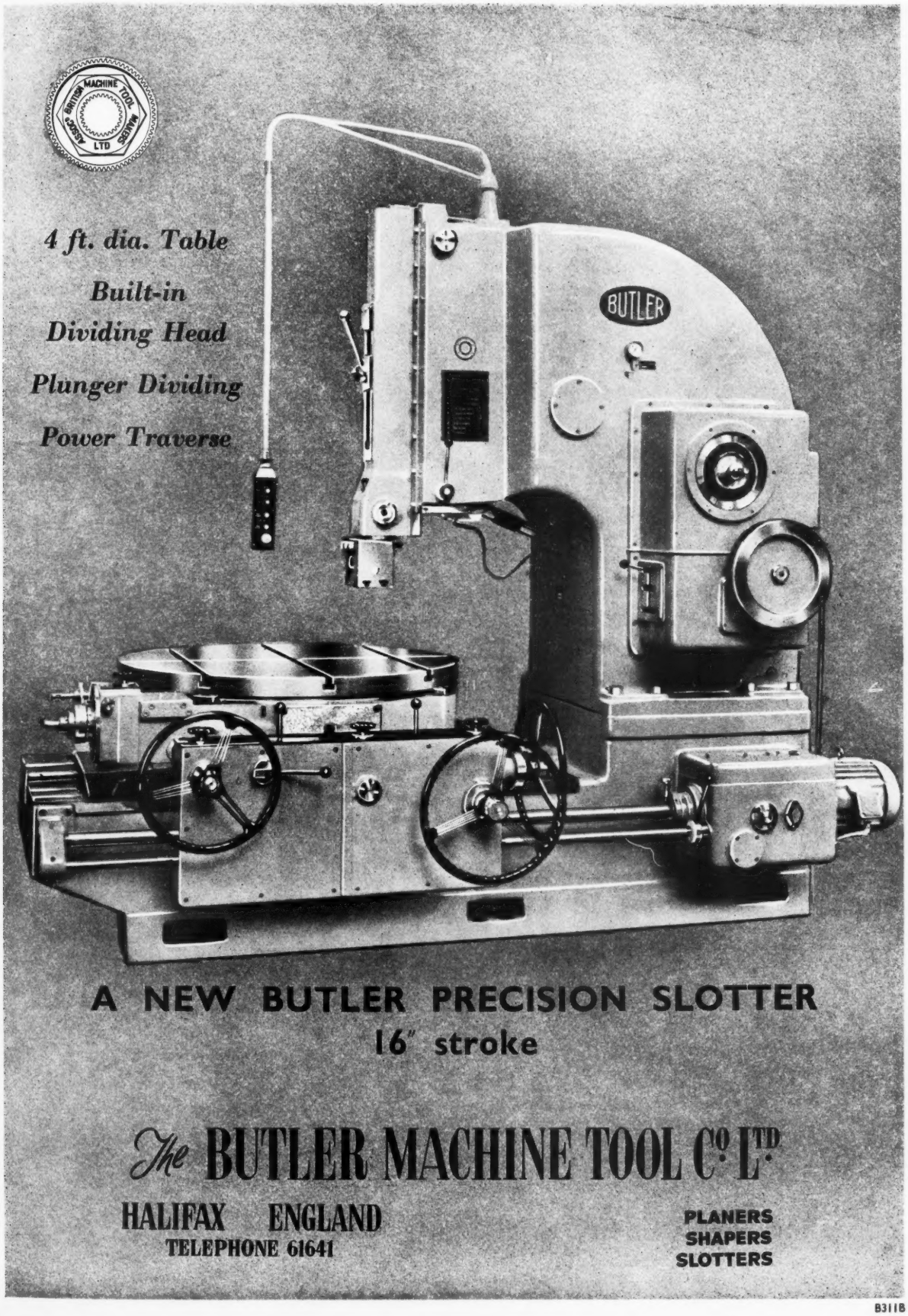
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4 ft. dia. Table
Built-in
Dividing Head
Plunger Dividing
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A NEW BUTLER PRECISION SLOTTER
16" stroke
The BUTLER MACHINE TOOL Co LTD
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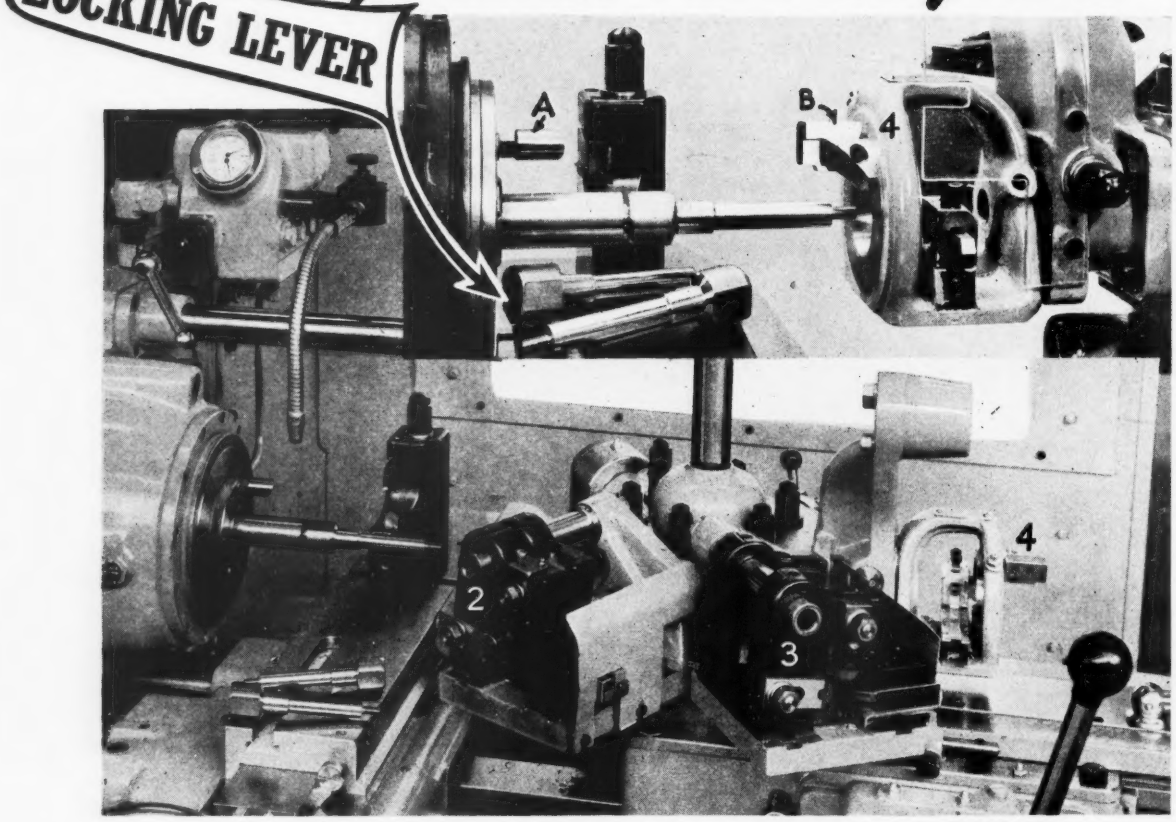
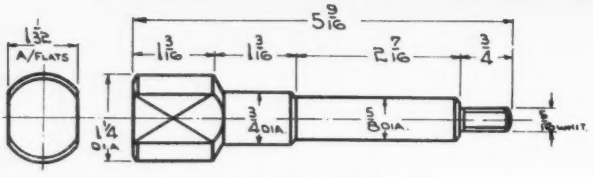
Maximum Production Special Tool Layouts





1¼ in Free Cutting Mild Steel, En.1.
Tungsten Carbide and H.S. Steel Cutting Tools.

Ward No. 3C CAPSTAN LATHE

FITTED WITH 1½ IN. AIR AUTO. BAR CHUCK AND AIR BAR FEED

DESCRIPTION OF OPERATION	Tool Position. Hex. Turret	Tool Position. Cross-slide	Spindle Speed R.P.M.	Surface Speed Ft. per Min.	Feed Cuts per inch
1. Feed to Stop and Close Chuck	1	—	—	—	—
2. Multi Roller Turn ¾" (Rough) and ⅝" dias.	2	—	1650	540	143
3. Multi Roller Turn ¾", 5/16" dias. and End	3	—	1650	540	143
4. Polygon Turn 1 1/32" A/Flats	4	—	636	208	143
5. Screw 5/16" Whit.	5	—	636	52	18 T.P.I.
6. Support. Chamfer and Part Off	6	Rear	954	312	Hand

Floor to Floor Time:
1 min. 40 secs. each.

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BIRMINGHAM 29
TELEPHONE SELLY OAK 1131

BRITISH MACHINE TOOL MAKERS ASSOC. LTD

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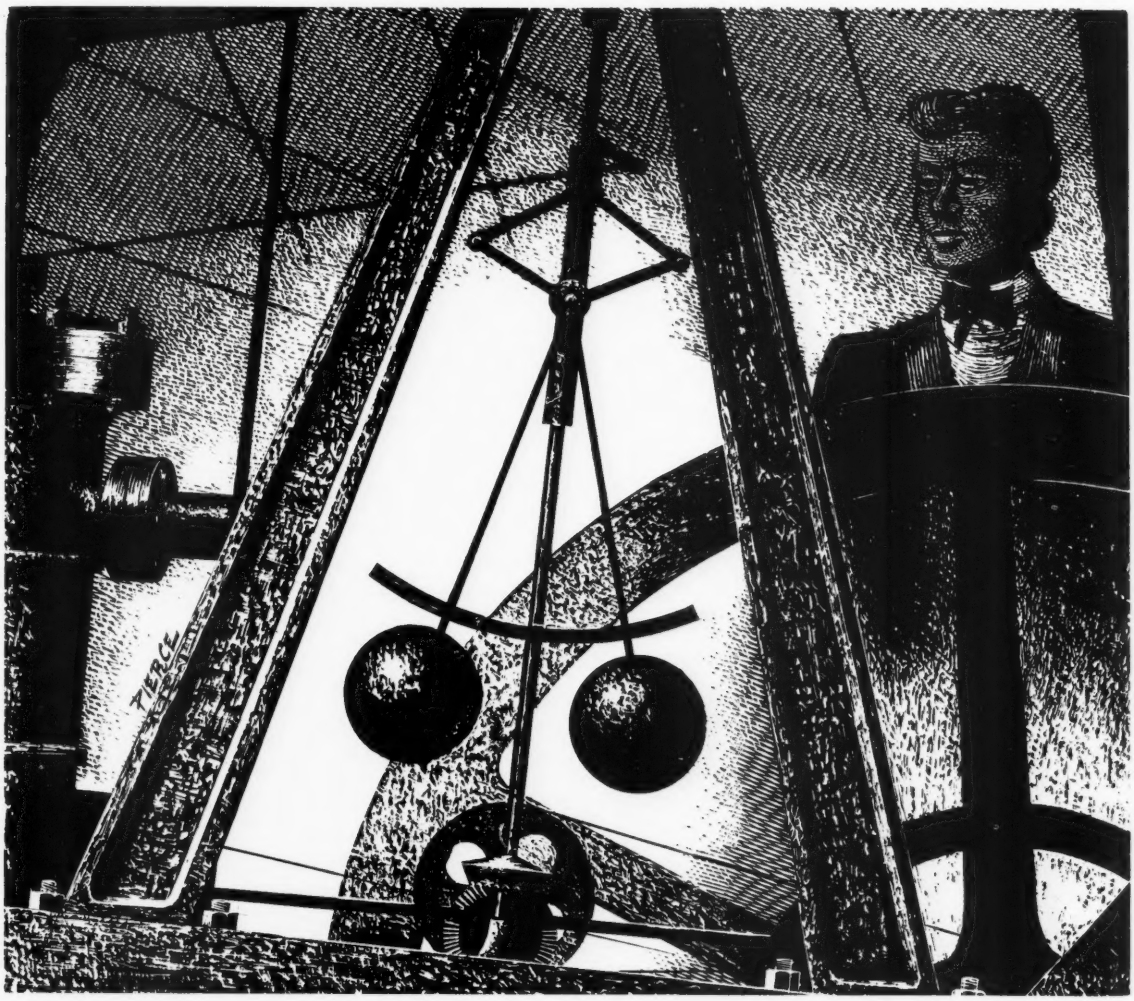

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"There is no new thing under the sun".

No new things, maybe: but many new *applications*. The governor on James Watt's famous steam engine was an early example of automation.

Today that word is on almost every lip . . .
today automation is on the march.

In this most significant industrial and social development,
"BROOMWADE" Air Compressors and
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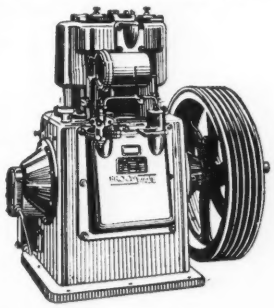
of reliability and efficiency for which they
have been known for the past half-century.



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AIR COMPRESSORS & PNEUMATIC TOOLS

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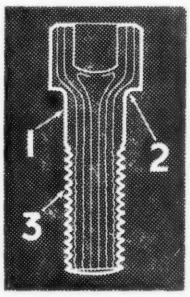
TENSILE STRENGTH AND THE FATIGUE FACTOR

MAYBE YOU CAN LIFT A SACK OF COAL. THAT'S STRENGTH, BUT WHEN YOU'VE BEEN DOING IT ALL DAY, THAT'S FATIGUE.

It has always been an easy matter to show a high Rockwell reading of hardness by merely heat treating any one of many varied steels. These steels may show up splendidly in a tensile test, but are completely worthless on today's higher speed machines and heavier stress forming service conditions. Why are they worthless? They have no fatigue life. Fatigue is a factor which has only received full consideration in recent years. It simply means that metal gets tired and gives way under continual stress, as when you bend a piece of wire back and forth until it breaks.

Unbrako technicians constantly strive to achieve the perfect balance between tensile strength and fatigue resistance. That is why Unbrako use only best quality Alloy Steel to their own exacting specifications, and make screws to the highest possible standards of unvarying precision. At the trouble spot under the head (1) *Unbrako have a fatigue-resisting fillet. At the thread root* (3), *fatigue resistance is greatly increased by the continuous closely-knit grain flow and rolled thread* (2) *and superior notch-free surface finish. No doubt, Unbrako make the world's finest screws and you can specify them with confidence. May we send you fuller details?*



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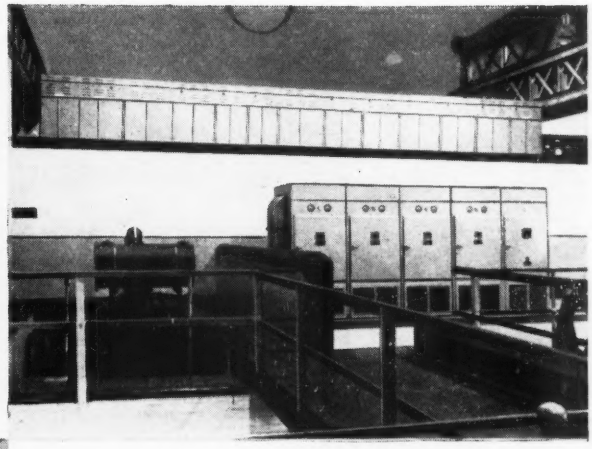
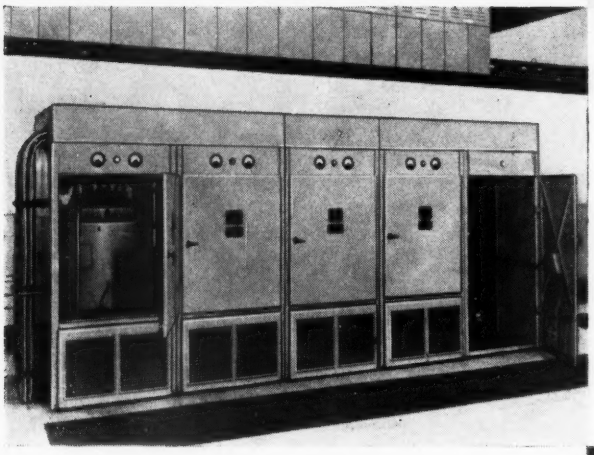
THE UNBRAKO SOCKET SCREW COMPANY LIMITED · COVENTRY

METROPOLITAN VICKERS

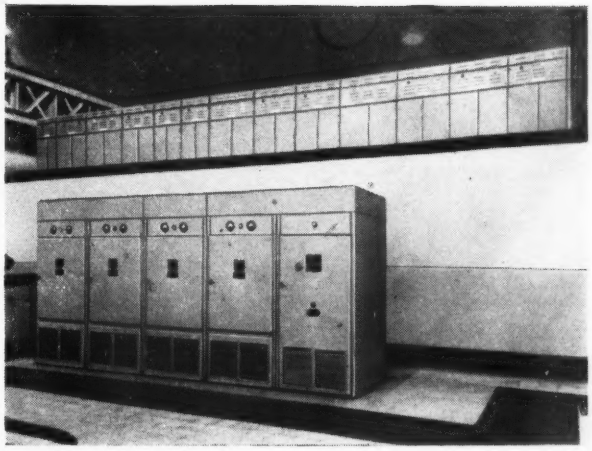
Rectifiers at Work





in steelworks

At the Ebbw Vale steelworks of Richard Thomas and Baldwins Ltd., steelworks auxiliaries are supplied from a Metropolitan-Vickers rectifier equipment rated at 1,000 kW 236 Volts D.C. A rectifier transformer feeds four air-cooled, pumpless steel-tank rectifiers of the Metropolitan-Vickers truck mounted, cubicle-enclosed design. Included in the equipment is an automatic high speed regenerative loading control cubicle of the electronically controlled ignitron type. The cubicle of the ignitron equipment matches those of the rectifiers.



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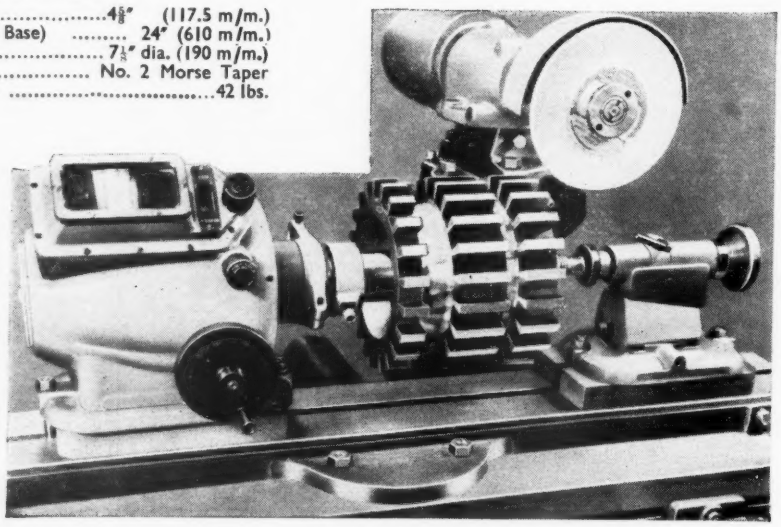

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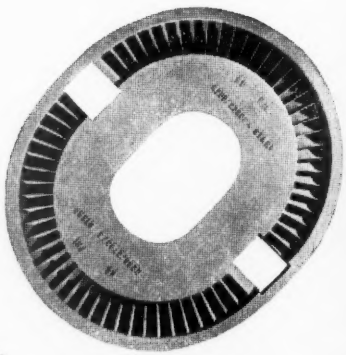
At F. H. Lloyd & Co. Ltd., where every new foundry technique is tried and tested before adoption, where rule of thumb is replaced by unsurpassed "know how", here the engineer is well advised to talk "design" with Lloyds experienced technicians first.



DIAPHRAGM: *Steam turbine component, weight 600 lbs., dimensions 3' 6" diameter × 2½" deep cast by F. H. Lloyd & Co. Ltd. for English Electric Co. Ltd.*

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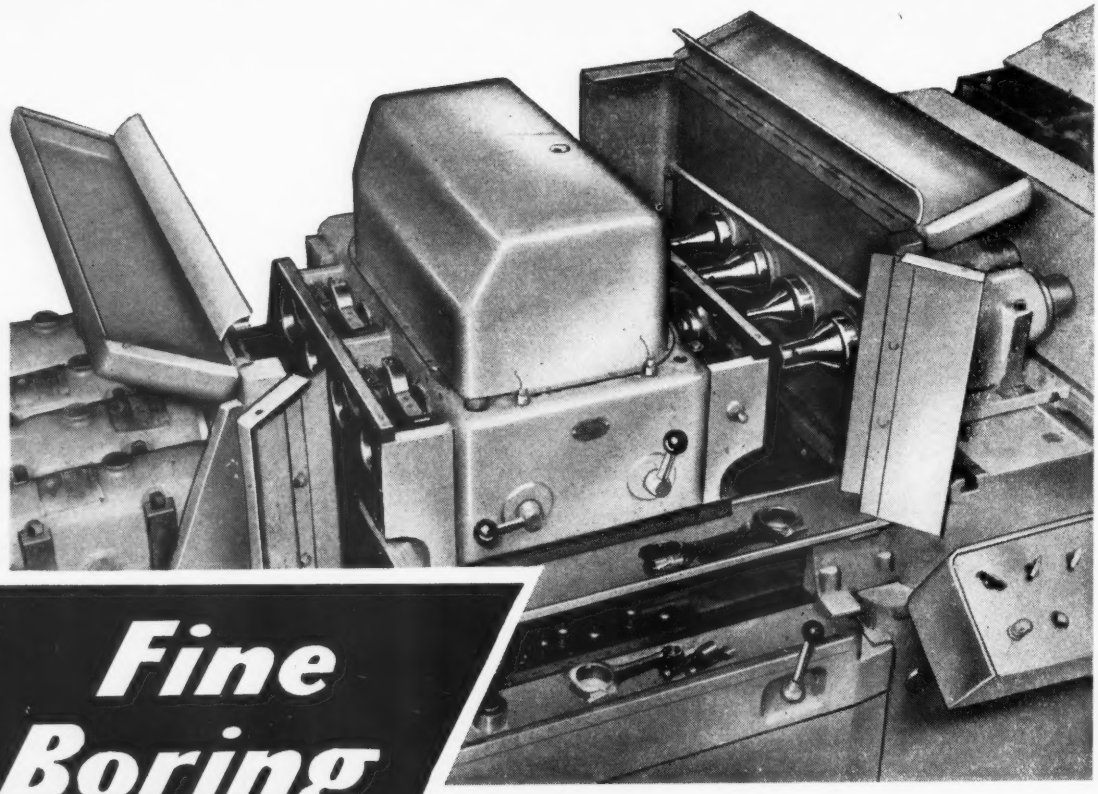

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The PRECIMAX Way

This PRECIMAX Model FB2 fine boring machines, installed at Vauxhall Motors Ltd., Luton, is specially tooled for finishing the large and small ends of two connecting rods simultaneously. Operation is continuous, one bank of four spindles boring while the other station is loaded. Air clamping is an additional aid to speedy production.

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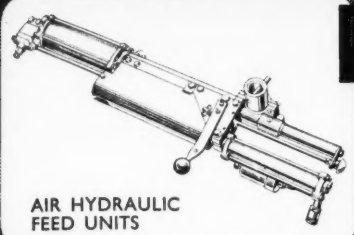

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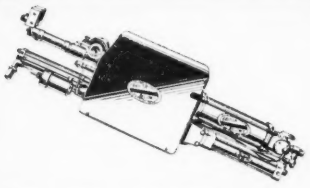

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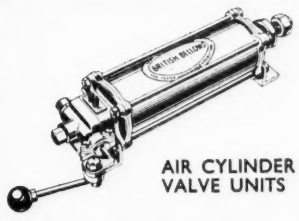

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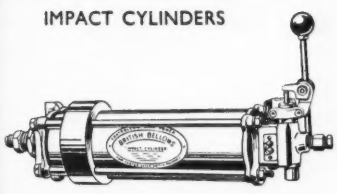

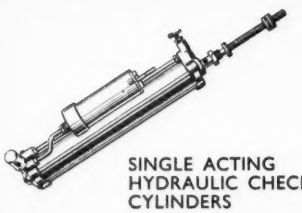

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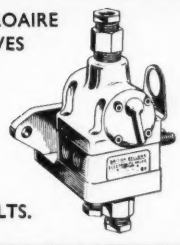

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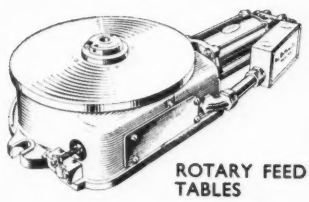

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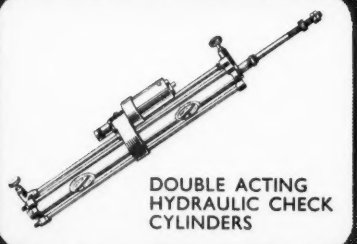

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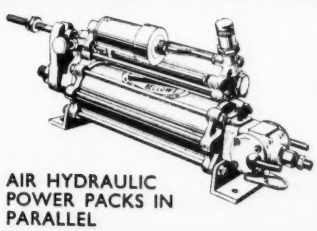

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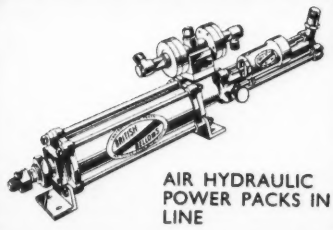
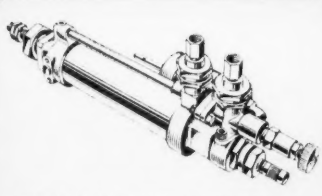


AIR HYDRAULIC POWER PACKS IN LINE



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PNEUMATIC EQUIPMENT

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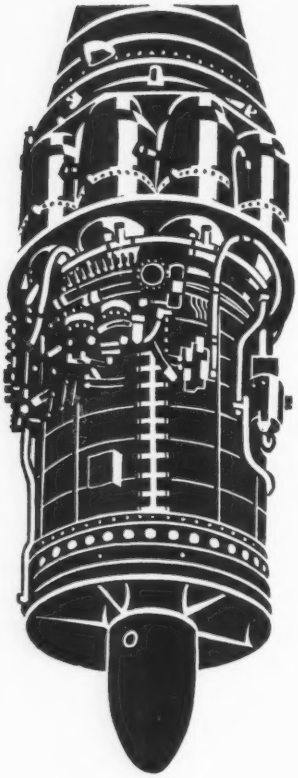

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to jelly babies

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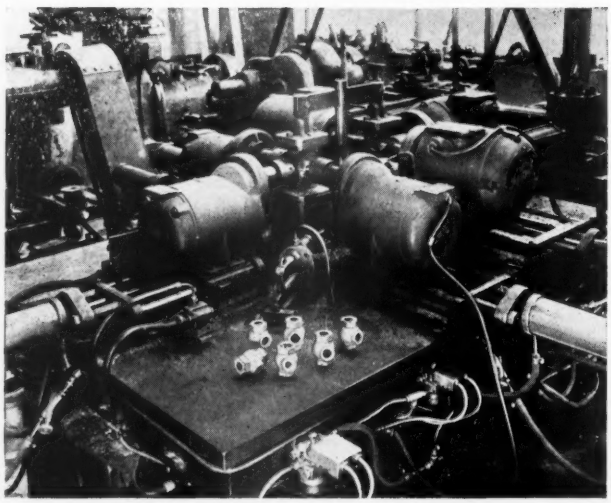

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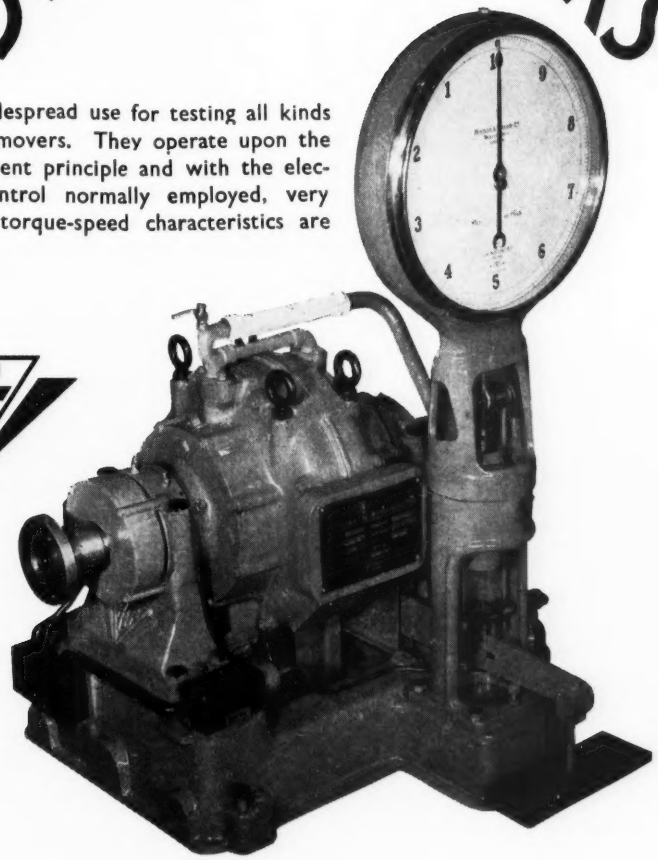

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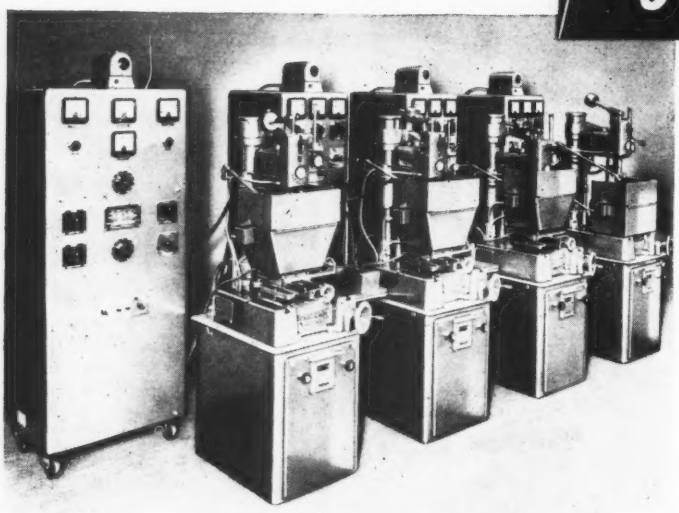
The leading manufacturers of spark machining equipment now introduce their latest

Mk III Model

6·5 kW



1 Harvester Tine forging die machined from the solid by Spark Machining in the hardened state

2 Jet Compressor Blade Forging Die reconditioned by Spark Machining

3 Layshaft Forging Die, preformed and finished by Spark Machining

A battery of four Sparcatron heads operated from one main control unit in conjunction with three auxiliary control units.

SPARCATRON

Manufactured by

IMPREGNATED DIAMOND PRODUCTS LIMITED
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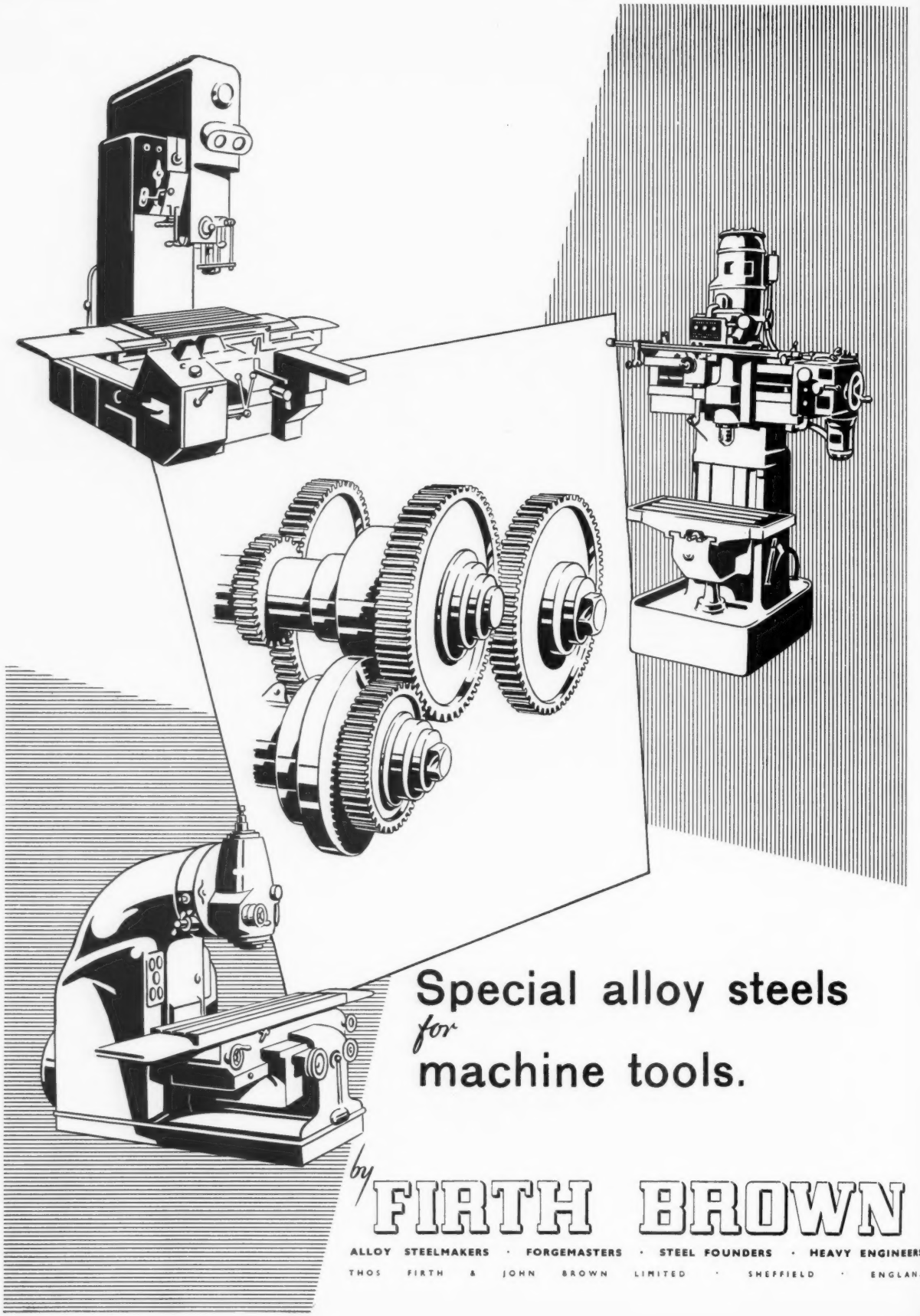
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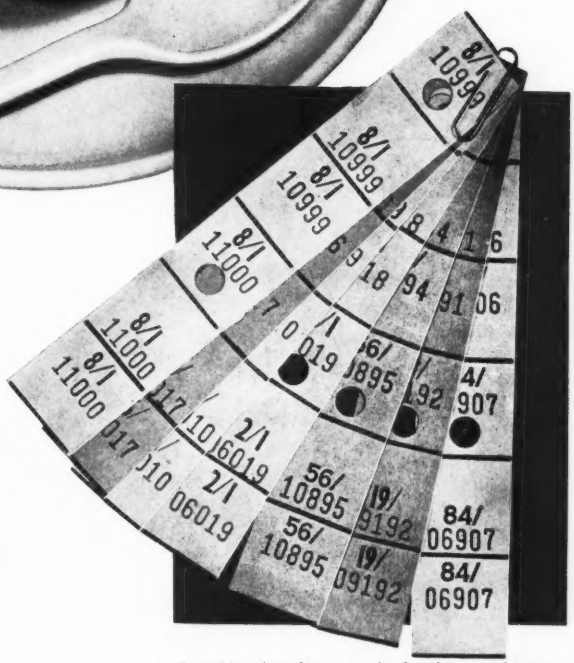

Laundries, these days, are using laundry tags of paper—wet-strengthened with Beetle Resins—a B.I.P. product. Even wet scrubbing has no effect on these tough tags. (Wet-strengthened paper made by Robert Craig & Sons Ltd., a subsidiary of the Associated Paper Mills Ltd.)

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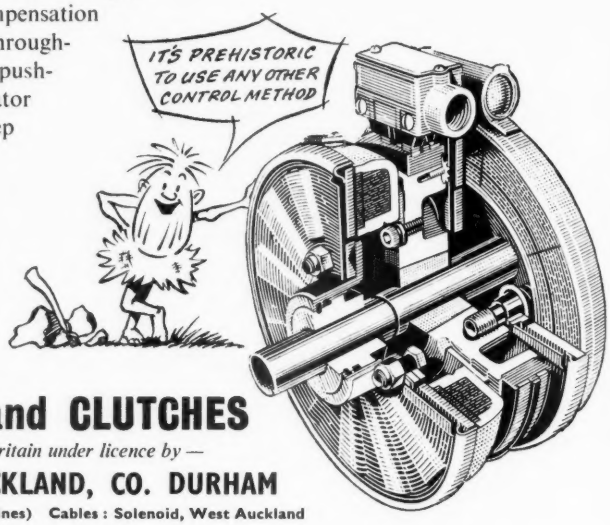

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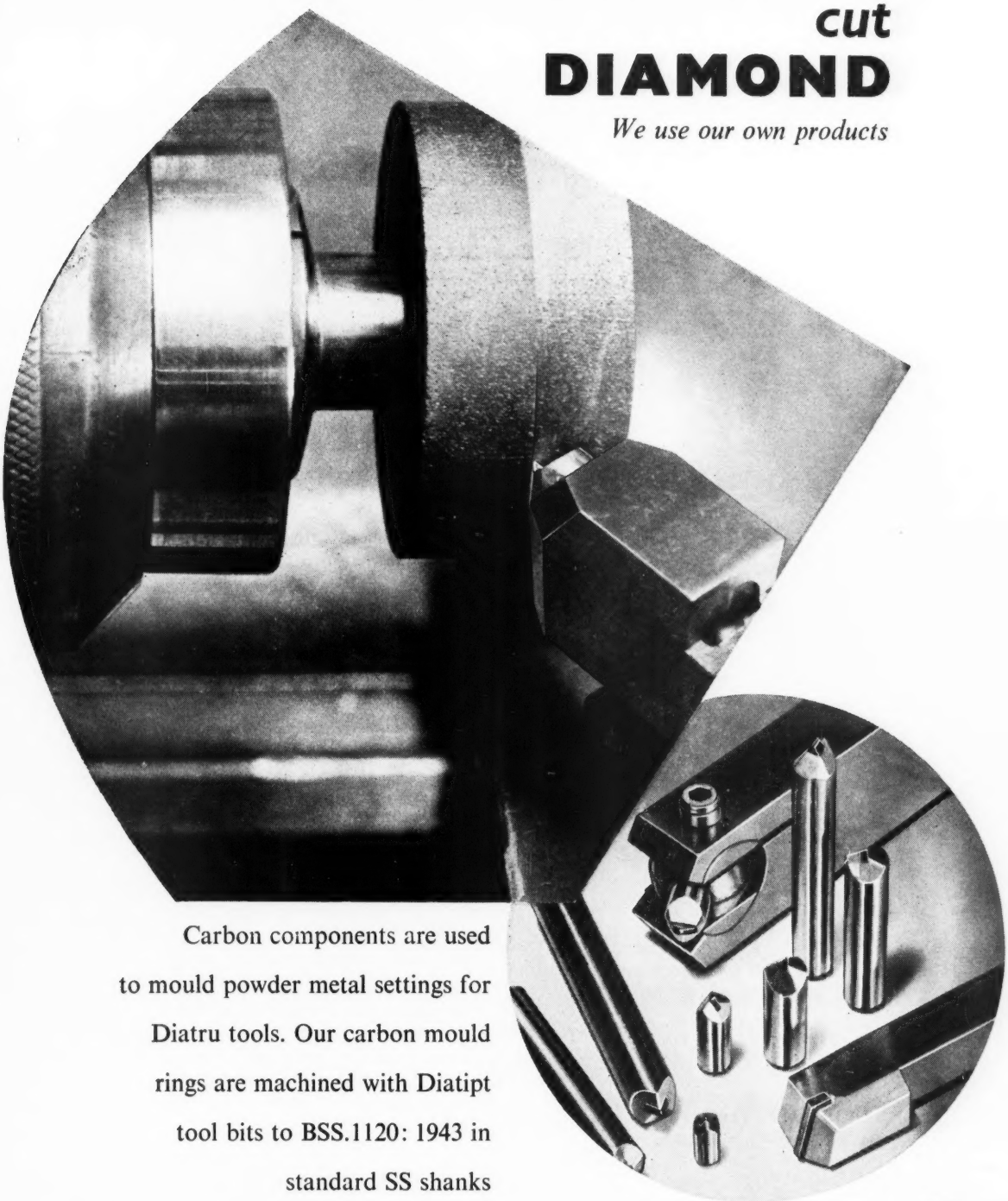

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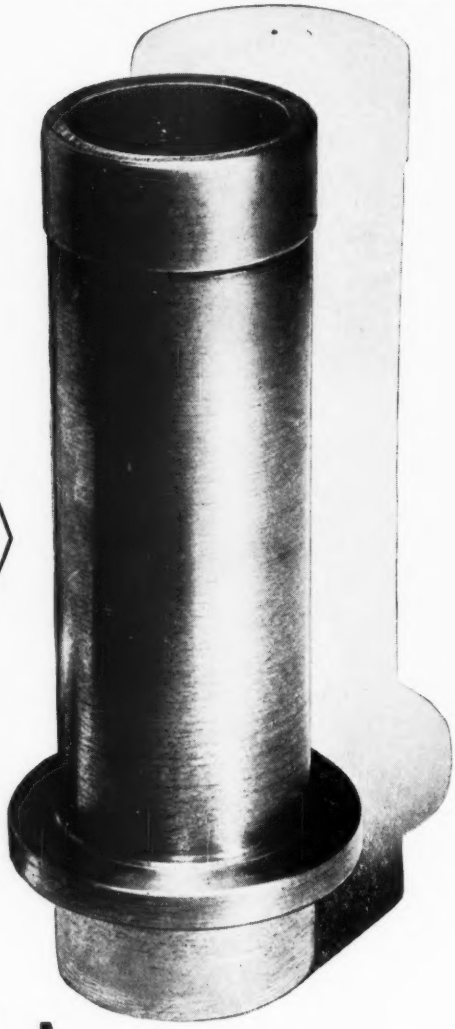
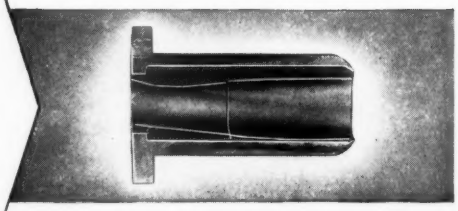


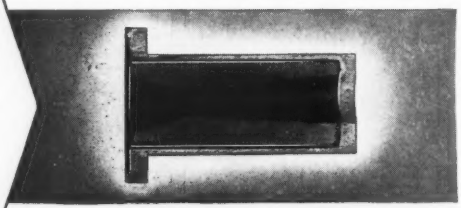
Seeing is believing !

The photographs below show the results of a comparative test made between a Tungsten Carbide Nozzle and a Carbon Tetra Boride Nozzle used with carborundum shot at an air pressure of 75-100 lbs per sq. inch.

The $\frac{3}{16}$" bore Tungsten Carbide Nozzle was worn to this condition in *two* weeks.



The $\frac{3}{16}$" bore Carbon Tetra Boride Nozzle with tapered lead-in was worn to this condition in *eight* weeks.



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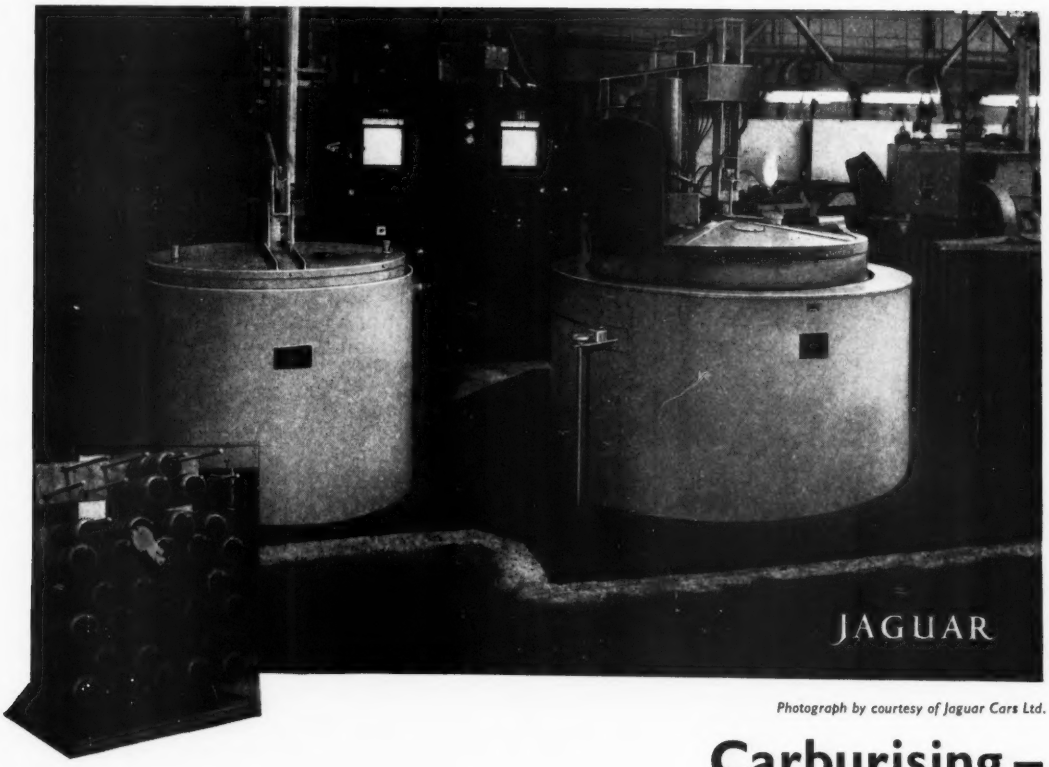

Photograph by courtesy of Jaguar Cars Ltd.

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Positive Instrument control of carbon

Nine hundred and ninety-nine out of a thousand production men have never seen a continuous instrument record of the percent carbon in a furnace carburising gas.

This invaluable information is now available to you as easily as a temperature record. It shows the percent of active carbon in the atmosphere of the L. & N. Homocarb furnace, and therefore the surface carbon content of the parts being treated. And further the actual percent carbon is entirely under your control — the carbon you get is the carbon you set on your Microcarb control instrument.

This carbon control unit is of major importance in that it results in a tremendous increase in the versatility of our world renowned Homocarb electric gas carburising furnace. In addition to its original function of case carburising it can now be used for carbon restoration, homogeneous carburising and hardening, with great advantage. In carburising, for instance, excess carbides can be prevented; networks and retained Austenite can be eliminated, this reducing rejects and lengthening the life of the product. When hardening, carbon pick-up and decarburisation are no longer problems, and distortion is practically eliminated. Carbon restoration and homogeneous carburising, previously difficult or impossible to control on production work, are now thoroughly practicable.

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The illustration pictures an installation working at Jaguar Cars Ltd.

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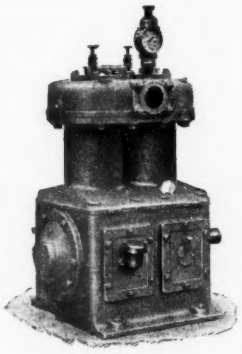

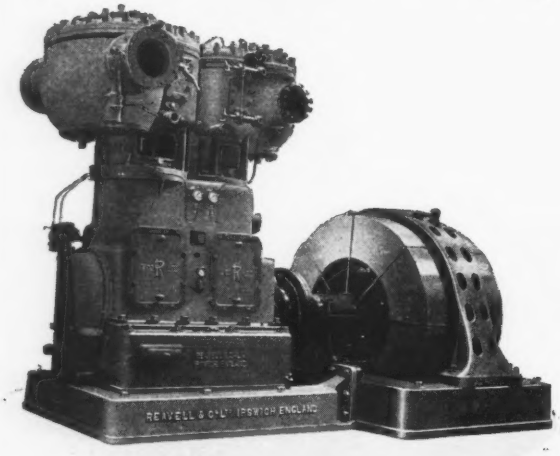

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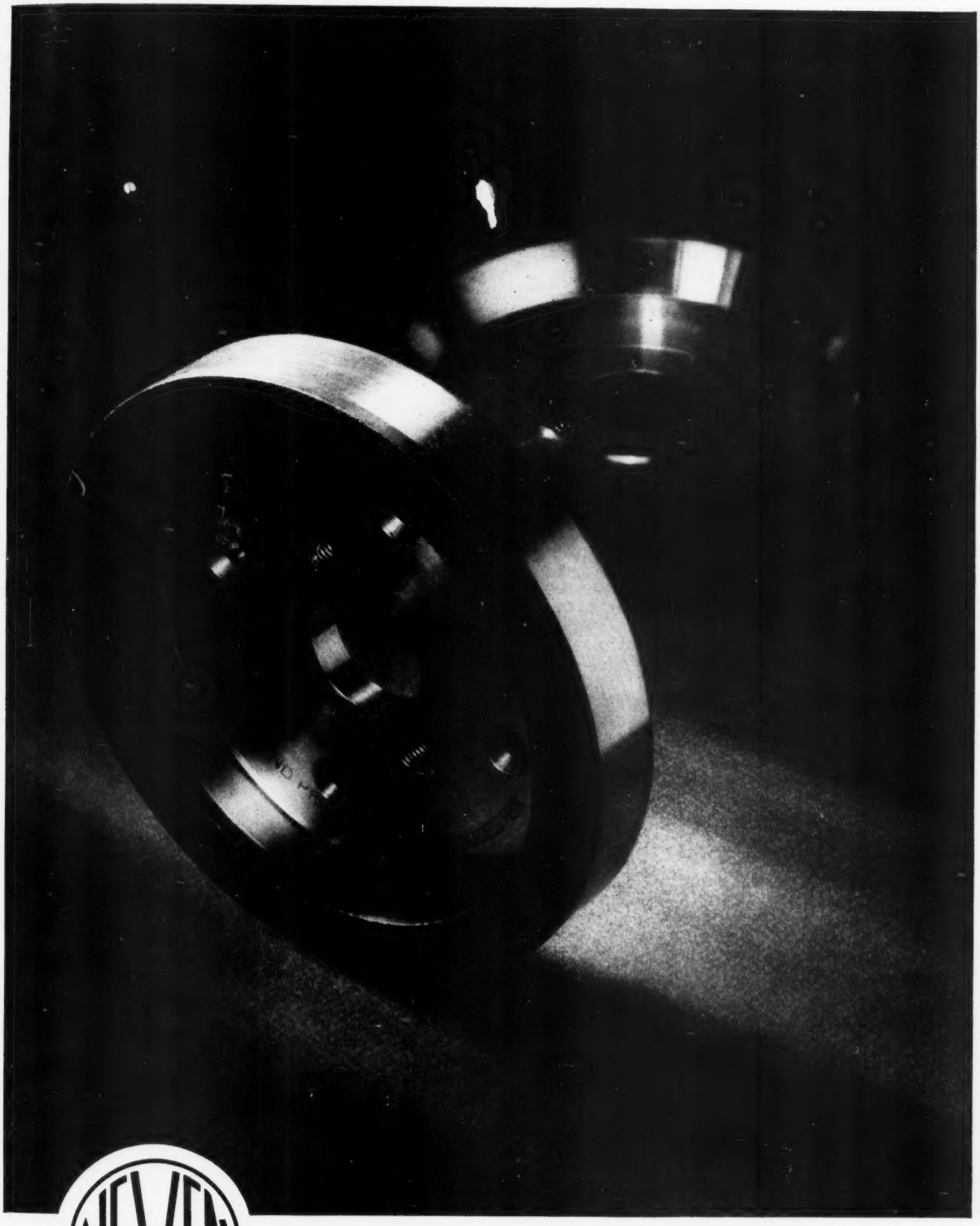

NEVEN

There are no better diamond tools than those manufactured by Impregnated Diamond Products Limited of Gloucester.

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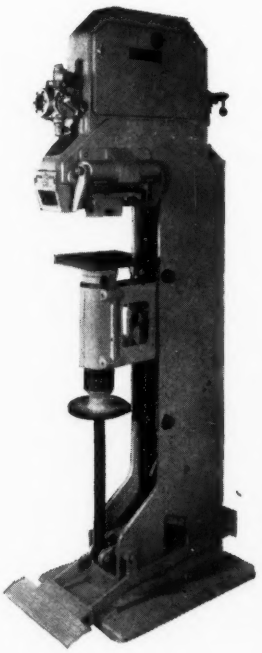
OUR LATEST E.P. 34 A
AIR-OPERATED MARKING MACHINE



This machine, the latest addition to the PRYOR range of marking equipment, simplifies and speeds up the marking of an extremely wide range of cylindrical and flat components. Air operation ensures exact uniformity of impression and reduces operator fatigue to a minimum. A full range of type holders, and geared roller-die carriers is available. Full details of this machine and of our hand-operated models will be sent on request.

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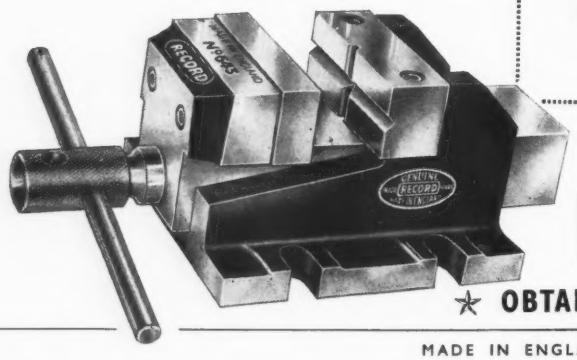

A sturdy and rigid tool for general production work supplied in three jaw sizes, 3" 4" and 5". The easily removable jaws can be quickly and inexpensively adapted either for holding components of diverse shapes, or as a basis for efficient and inexpensive jigs.

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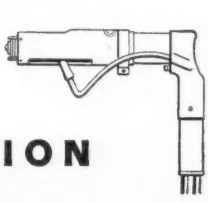

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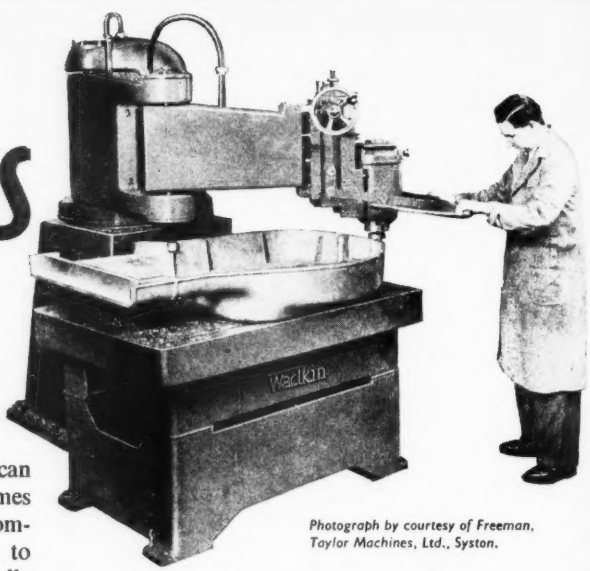
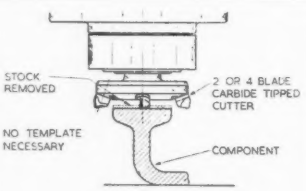
NON-FERROUS METALS



Photograph by courtesy of Freeman, Taylor Machines, Ltd., Syston.



The high cutting speeds employed, namely 12,000 and 18,000 r.p.m. and the low tooth loading of the cutter makes routing particularly suitable for face milling components such as the machine guard shown above.

Wadkin Routers can reduce production times on Non-ferrous components from hours to minutes. With spindle speeds up to 18,000 r.p.m. the metal is cut at the highest possible surface speed. That's why a metal removal rate of 20 cu.in./min. is easily accomplished. The Articulated Arm Router is the latest development of the radial arm type. Full details of this machine are given in Leaflet 831, available on request.

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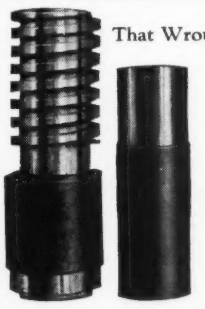

That Wrought Iron has outstanding machining properties is strikingly demonstrated by these typical test pieces. Its ductility is equally notable, while its essentially fibrous character gives it a toughness which enables it to stand up to severe vibrations, absorb varying stresses and recover from sudden shock.

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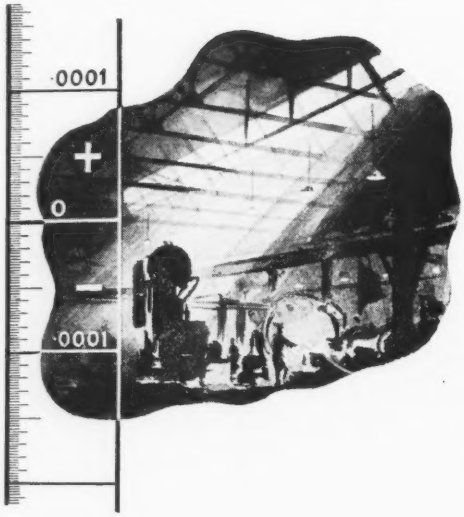

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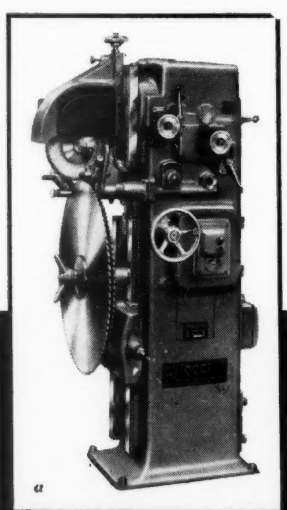

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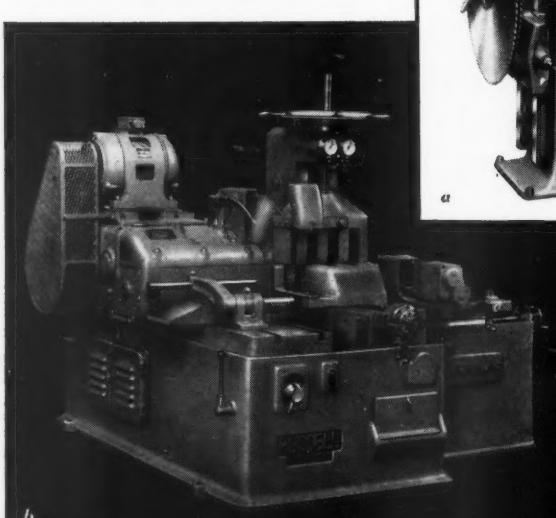

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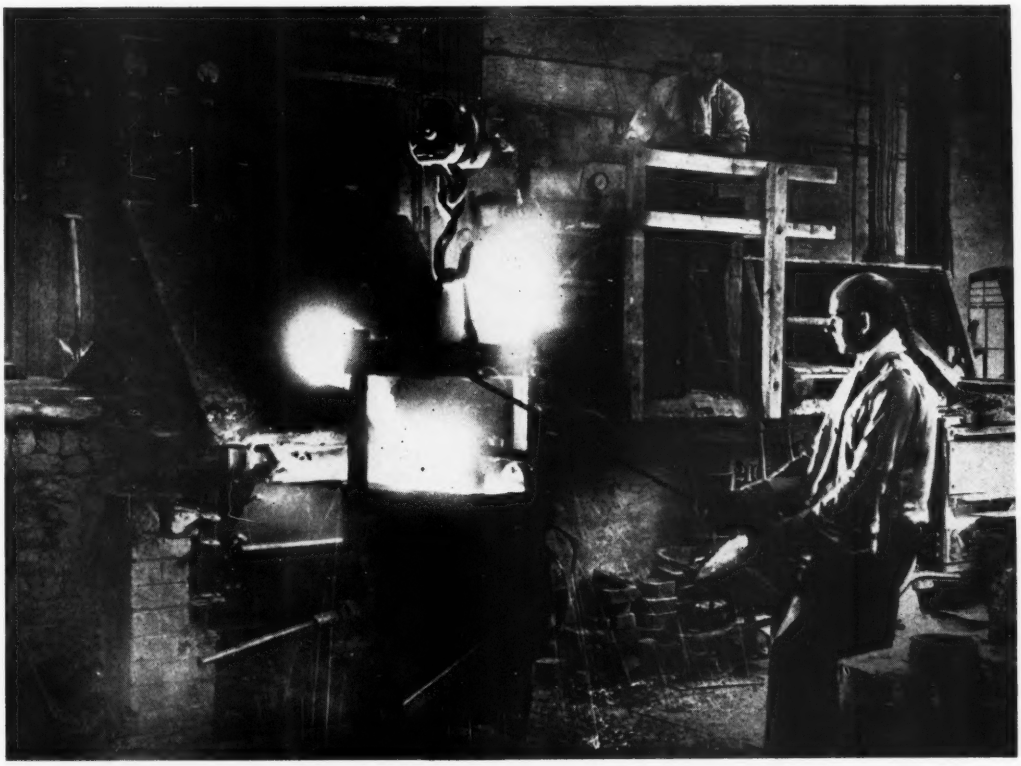

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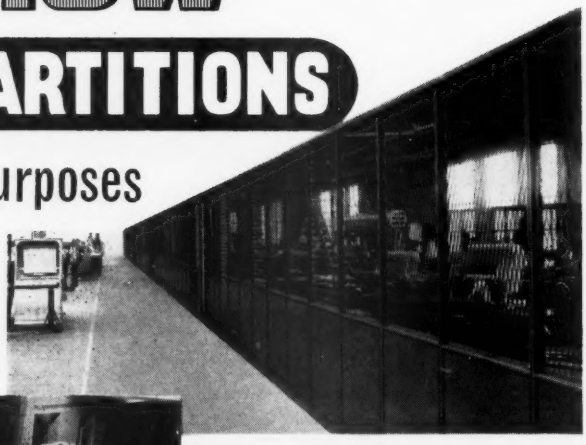

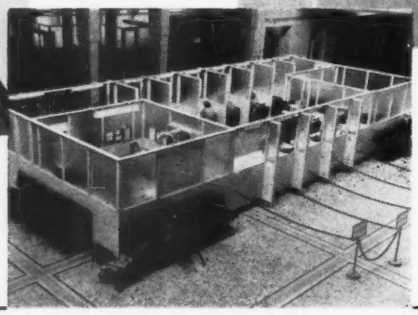

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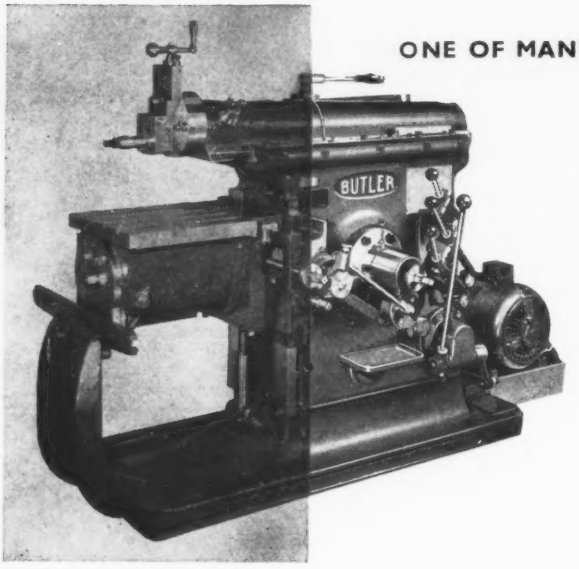

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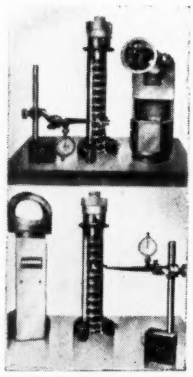

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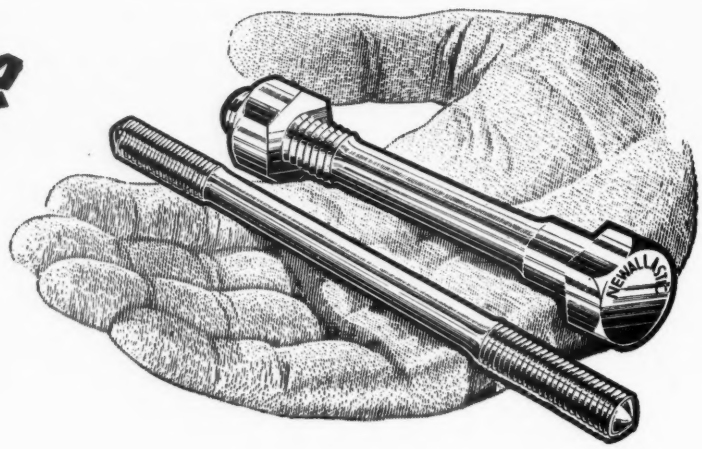

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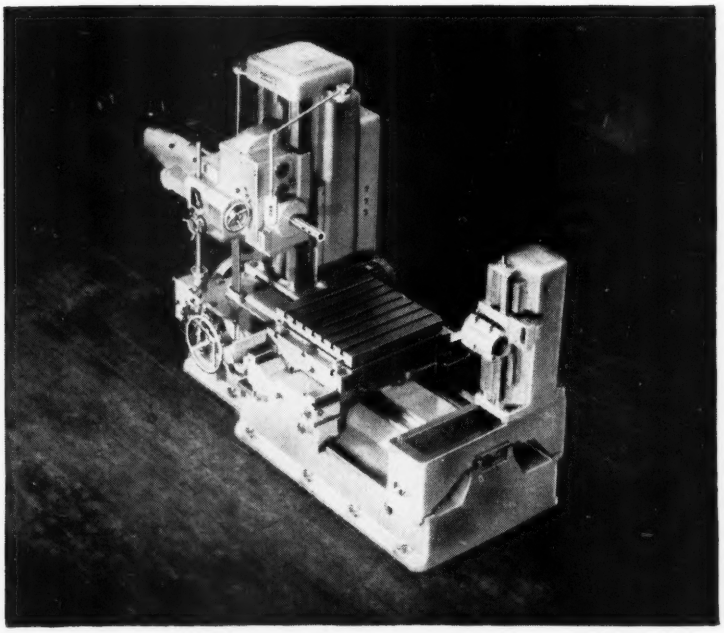

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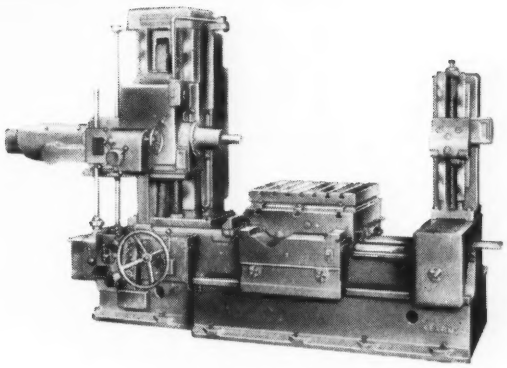

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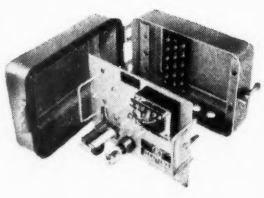

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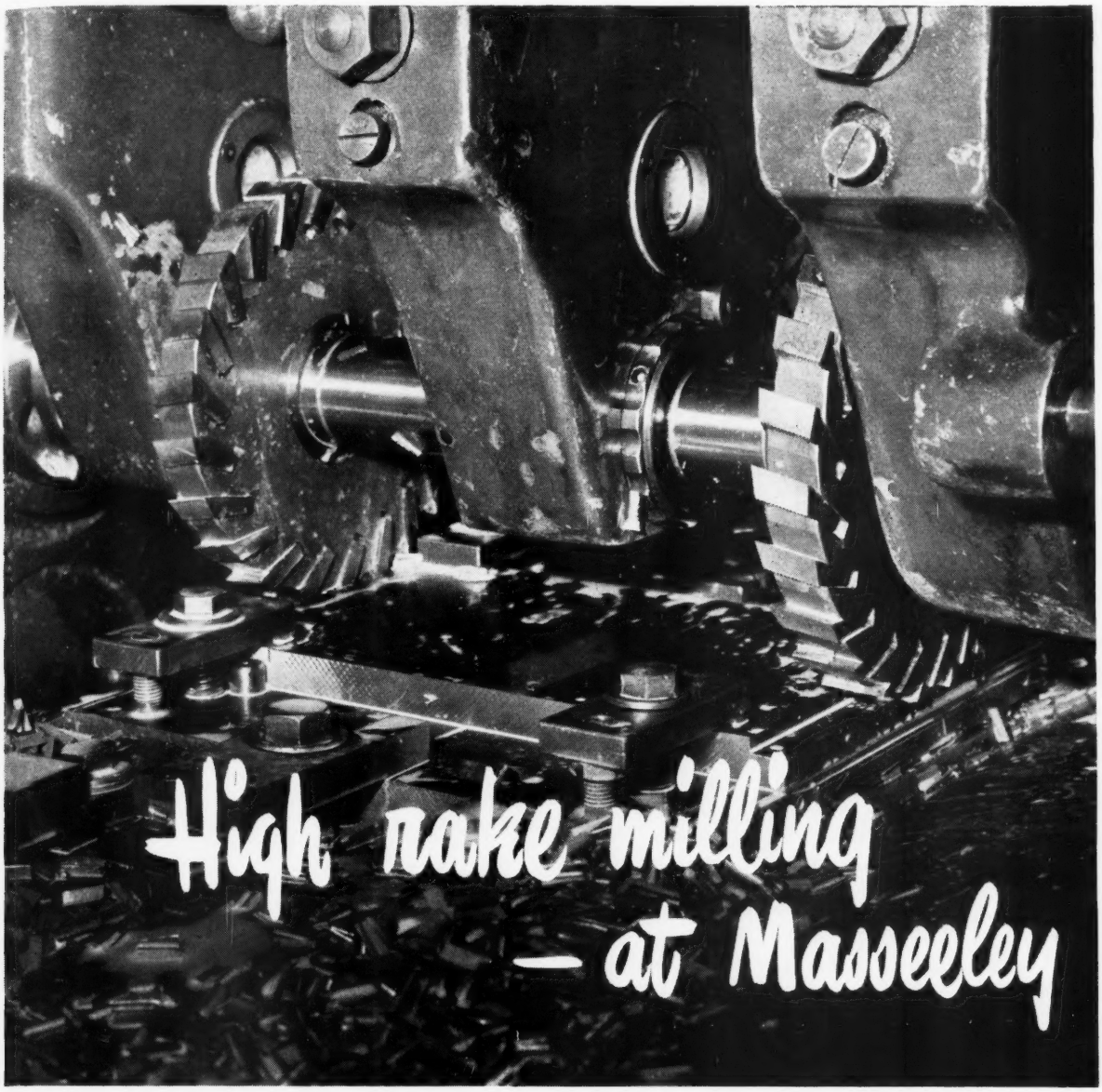

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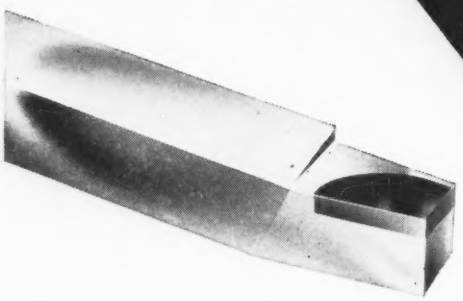

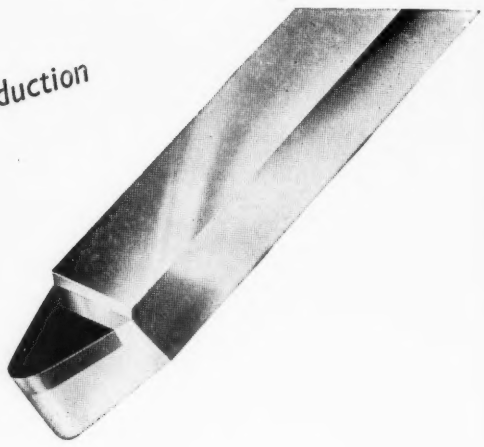

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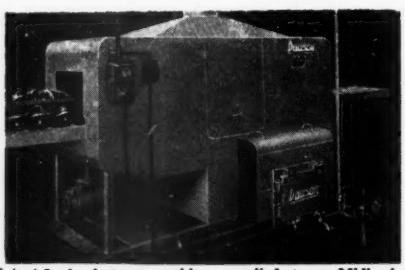
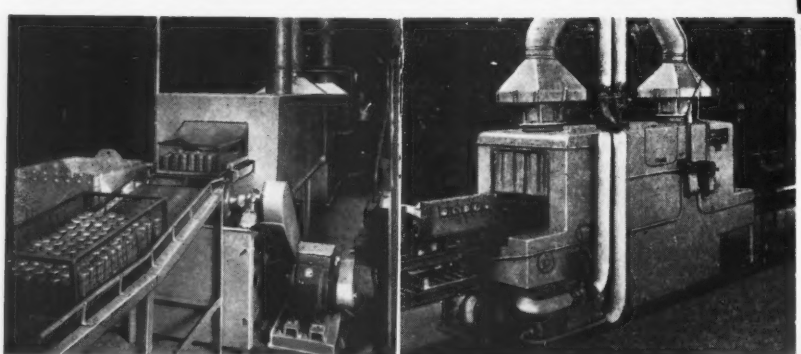


A 'Junior' type machine supplied to a Midlands Motor Car Works.



Supplied for the washing and drying of Tractor parts. Crank Shafts, Sumps, Pressings, etc.

A model 'A' machine, washing parts of motor car engines prior to assembly.

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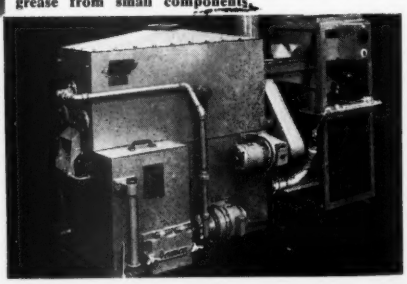
DE-GREASING AND CLEANING MACHINES

A Rotary Drum machine for removing swarf and grease from small components.



Dawson Metal Parts cleaning machines are supplied for all branches of the engineering industry. Their chief characteristics are robustness of design, small number of working parts and simplicity of operation. Space only permits the illustration of four of the many types of machines built for quick economical washing and drying of Metal Parts.

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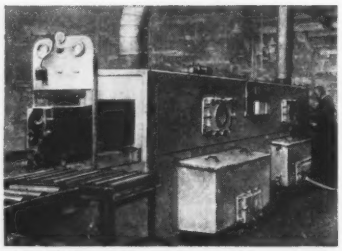
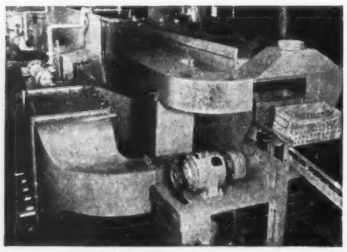
INDUSTRIAL CLEANING MACHINES

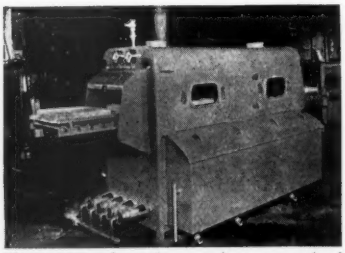
can be designed to meet your particular cleaning problems



This illustration shows a machine cleaning crank cases in the production line. It is equally capable of cleaning small parts in baskets.



A power driven conveyor system is employed with this cleaning machine for ball bearings.



Trays carrying the work are pushed through on a roller conveyor by hand in this cleaning installation.

Whilst offering a very wide variety of standard cleaning equipment, it is BRATBY policy, wherever possible to design the machine to meet the particular cleaning problem. Careful study of each individual problem ensures maximum efficiency and economy of the plant in operation. The illustrations show but a few of the specific types of Cleaning Machines designed by BRATBY for individual needs.

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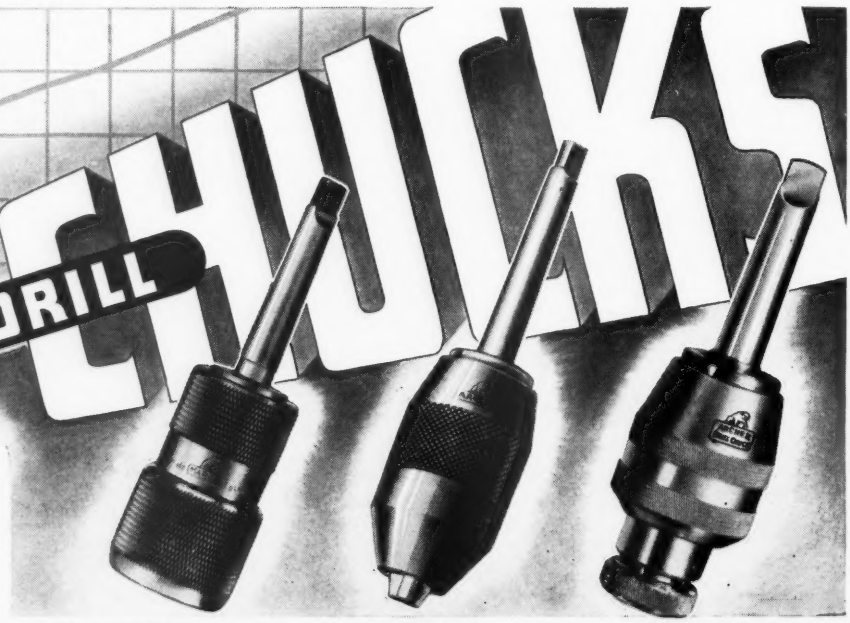

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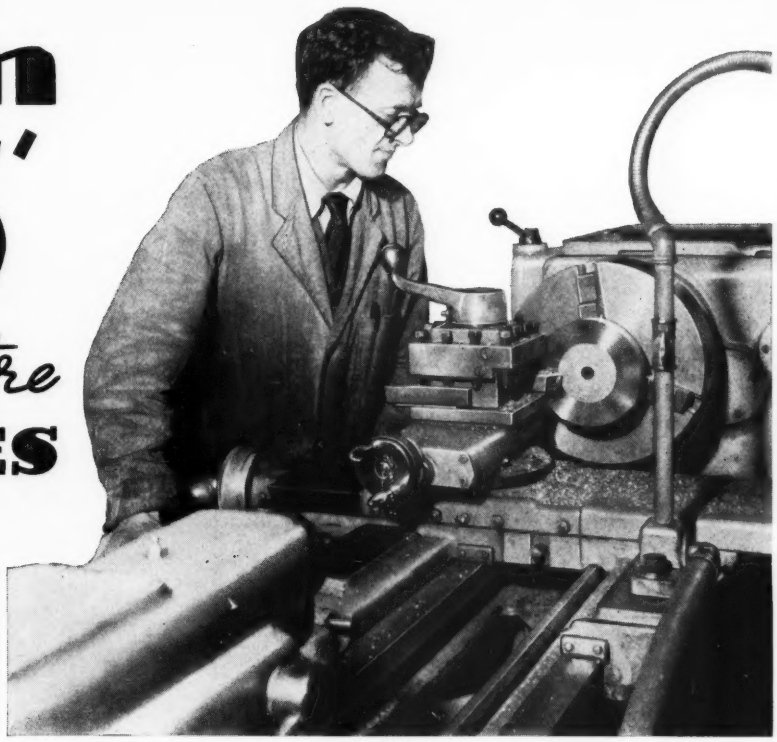

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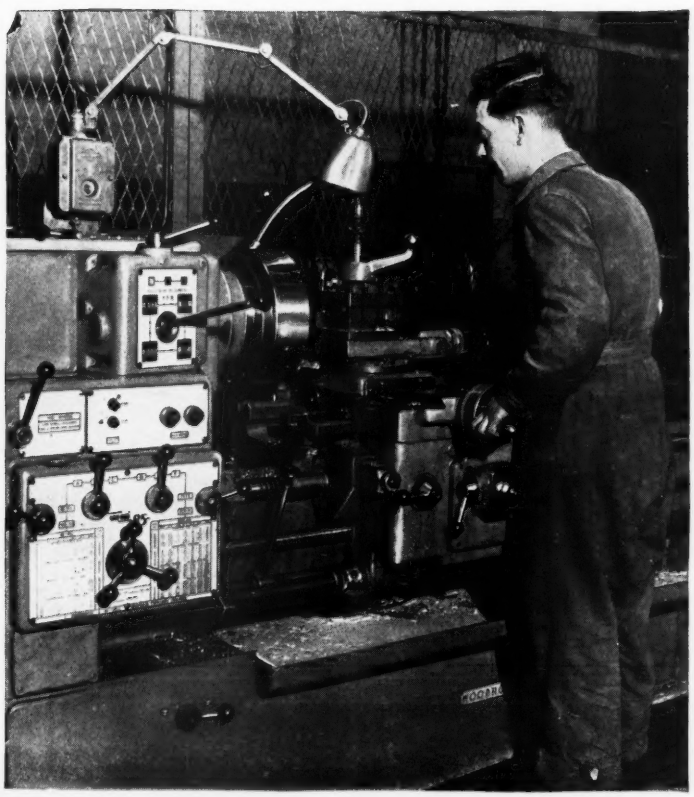

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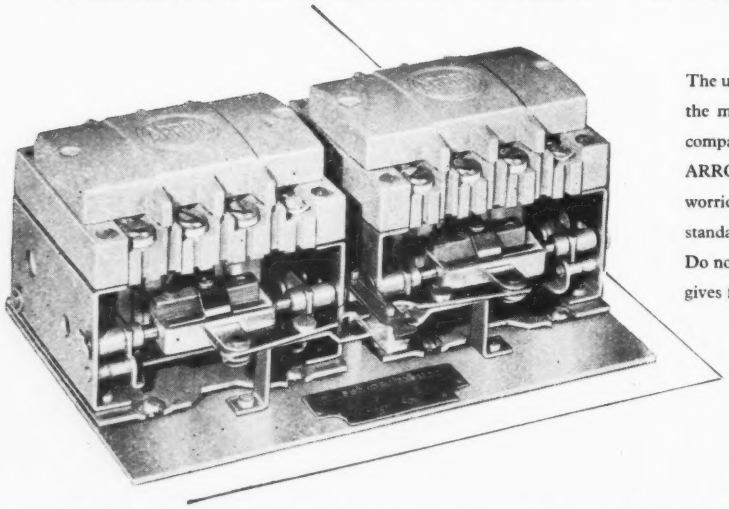

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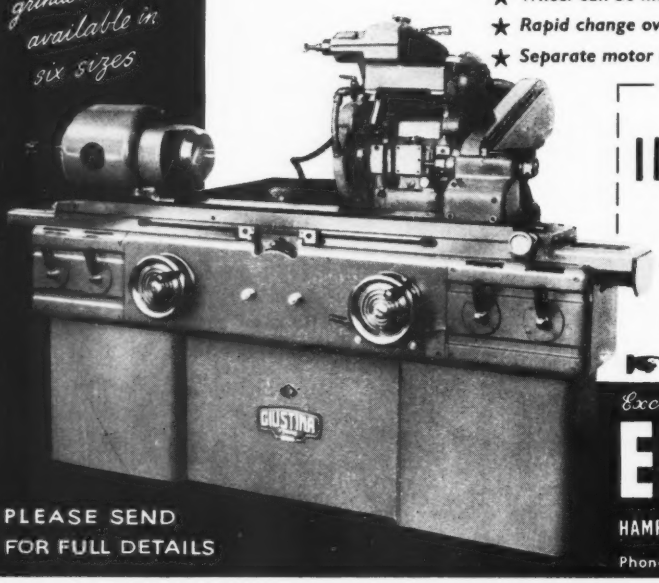

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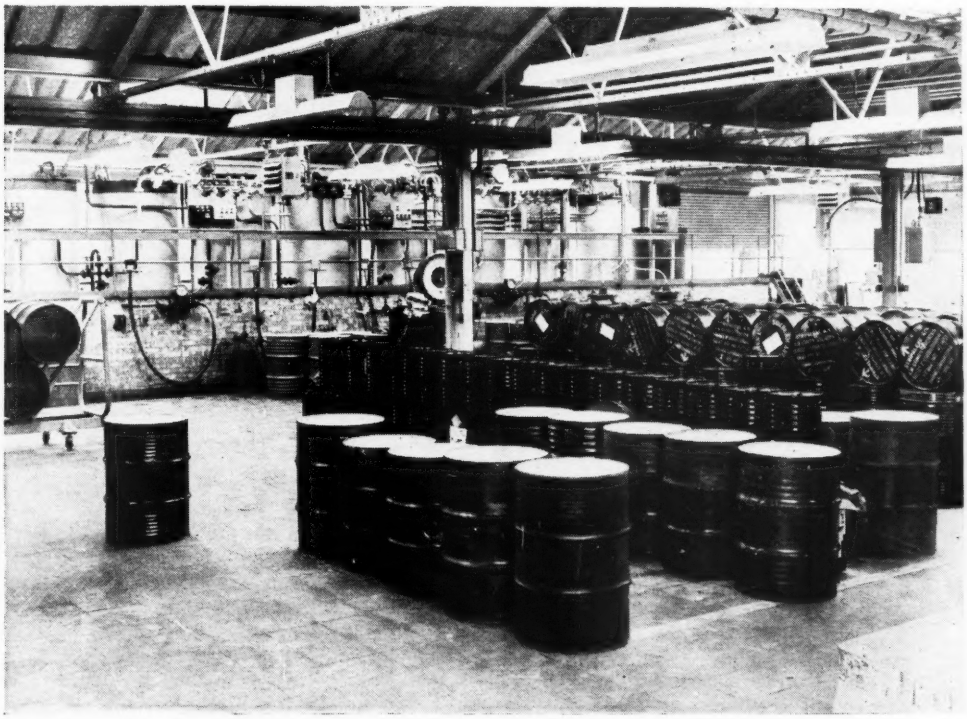

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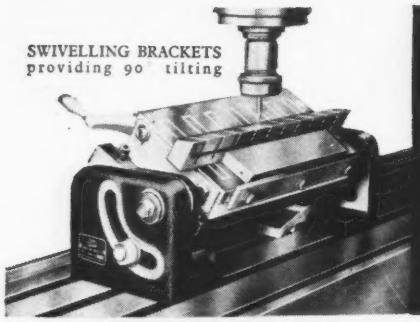

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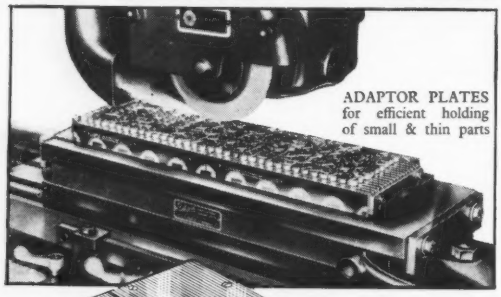

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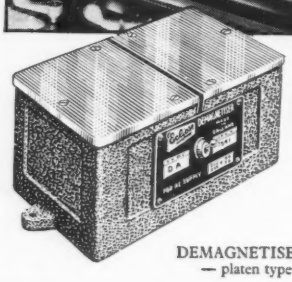

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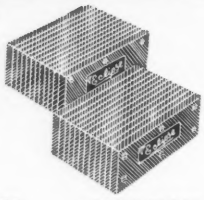

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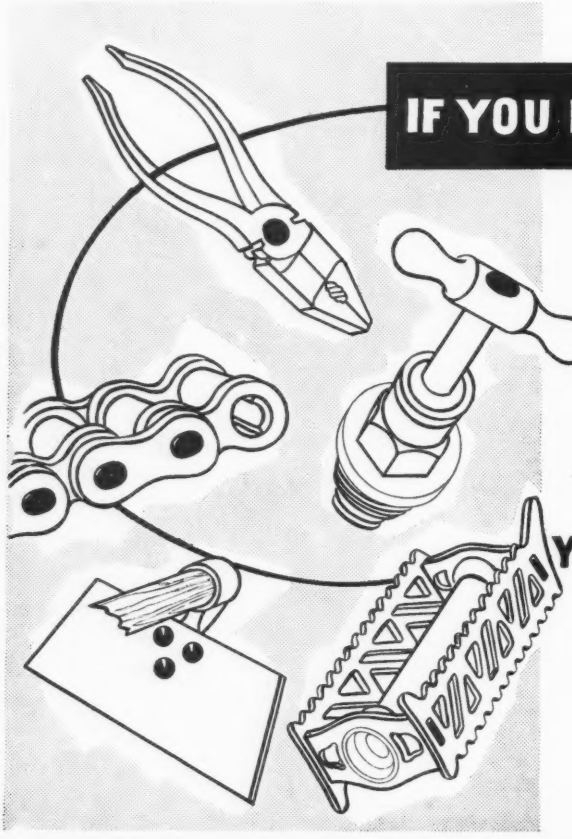

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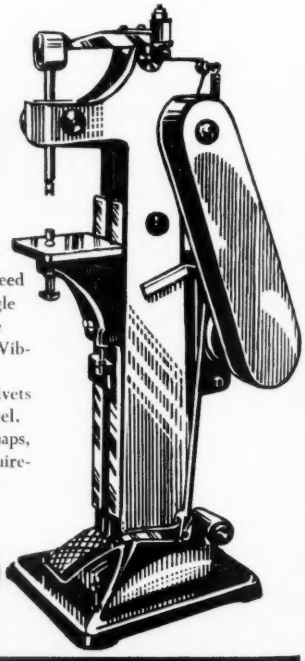

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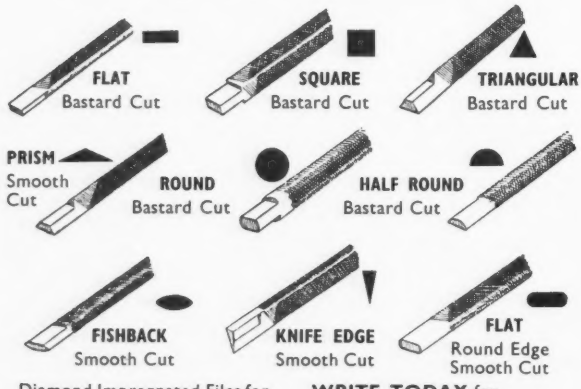

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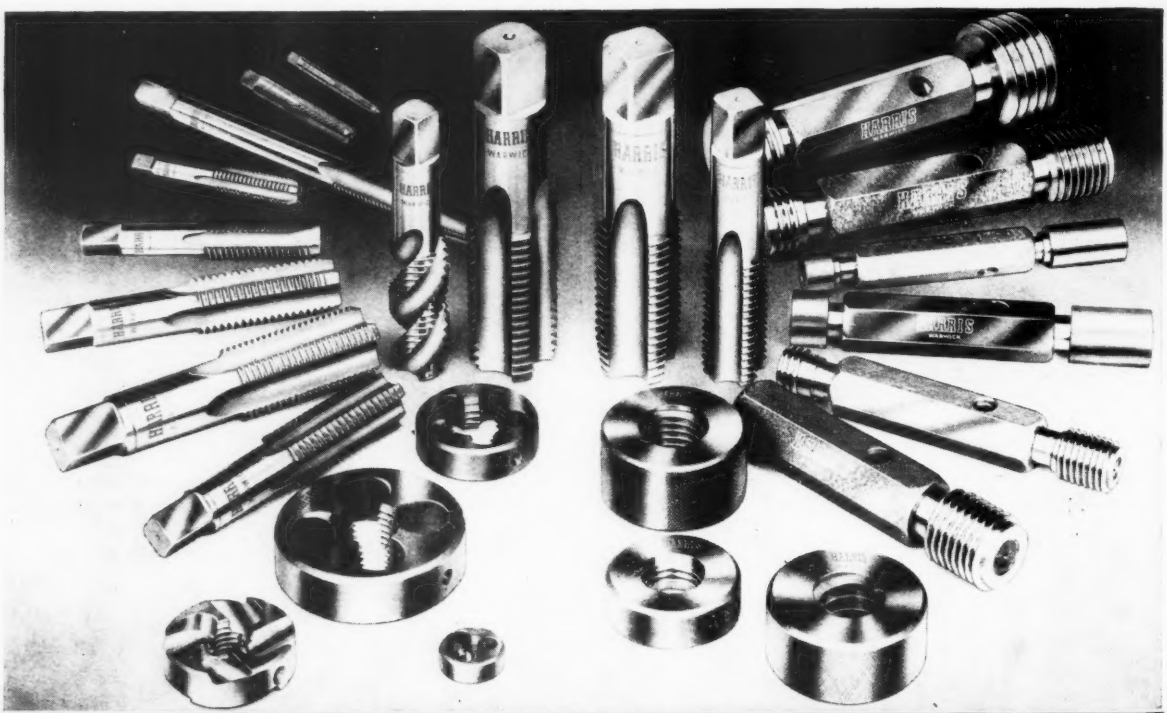

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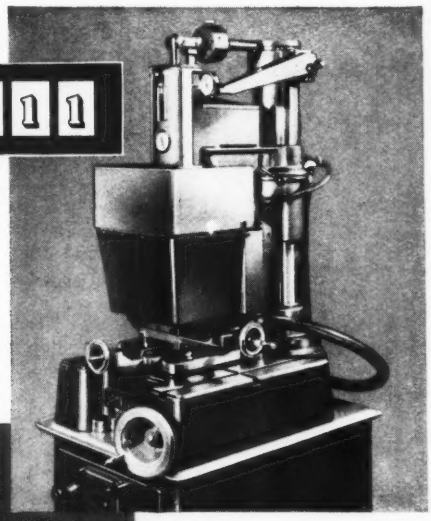

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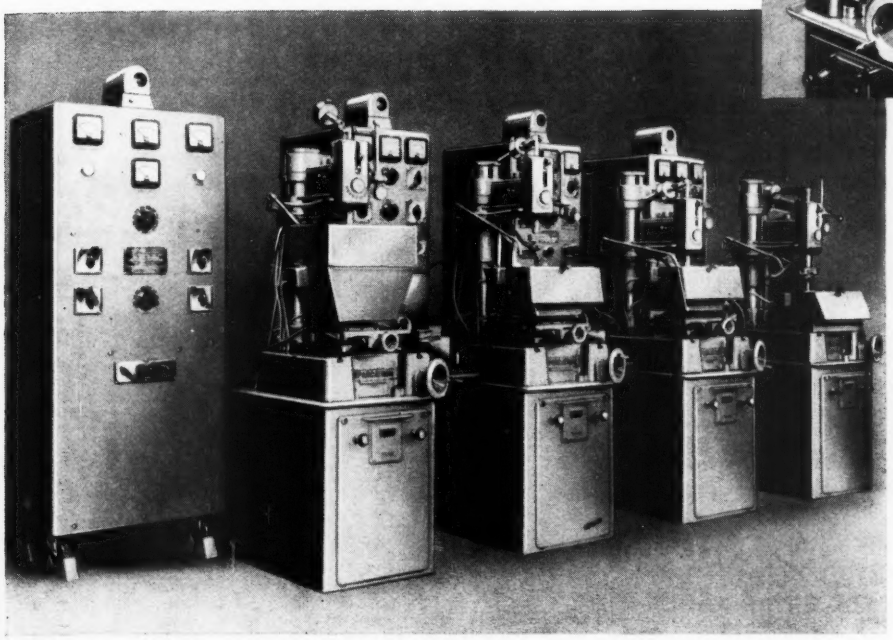

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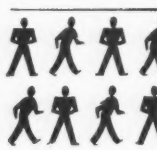

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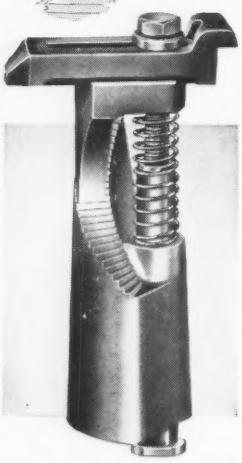

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1 5	$4\frac{3}{4}$ - $7\frac{3}{8}$"
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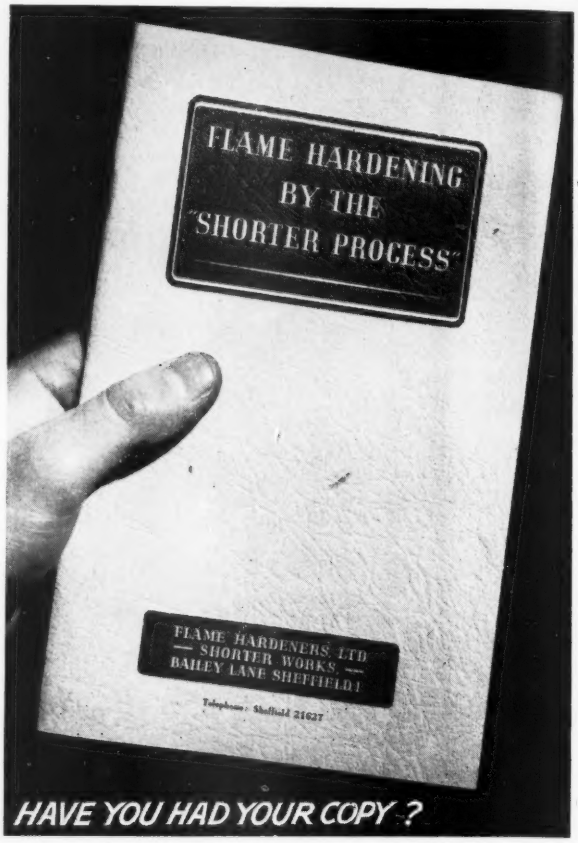
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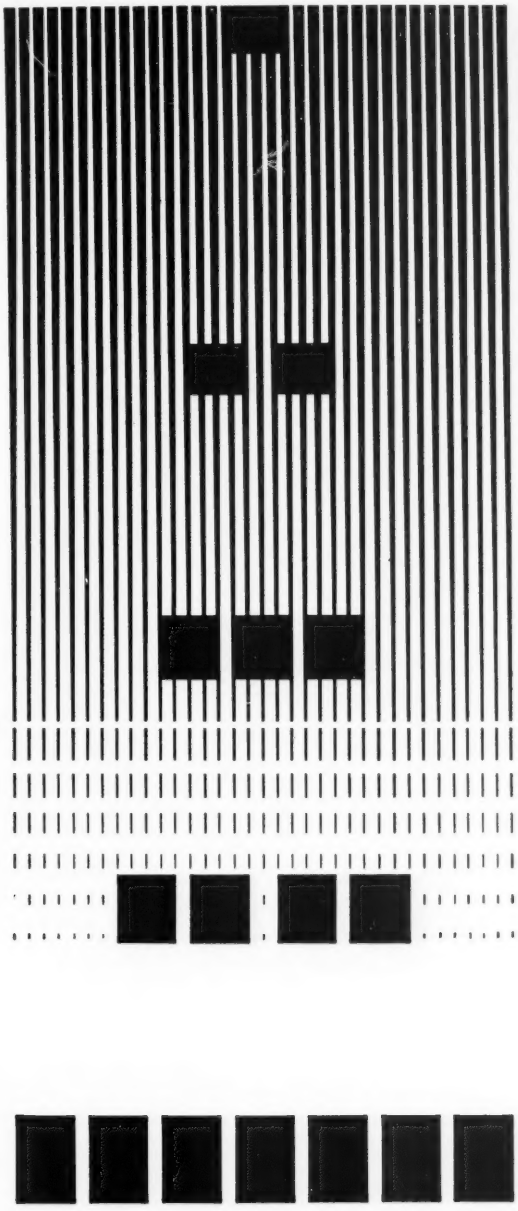

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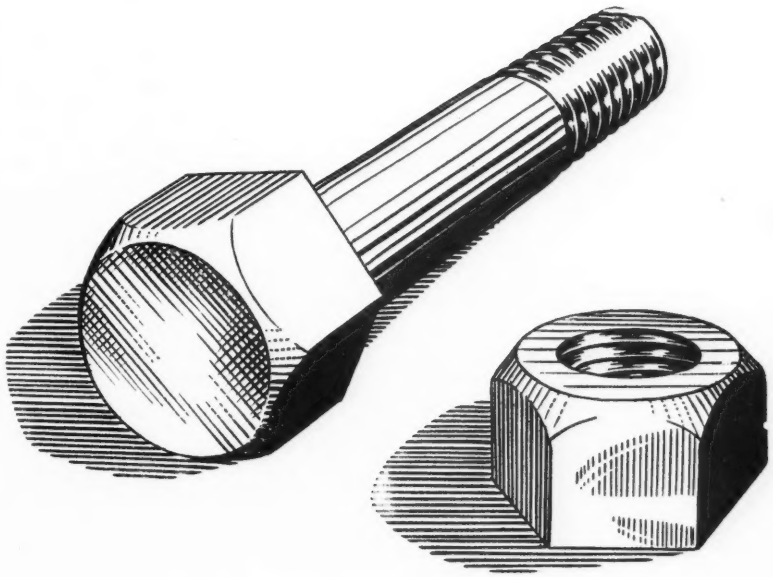

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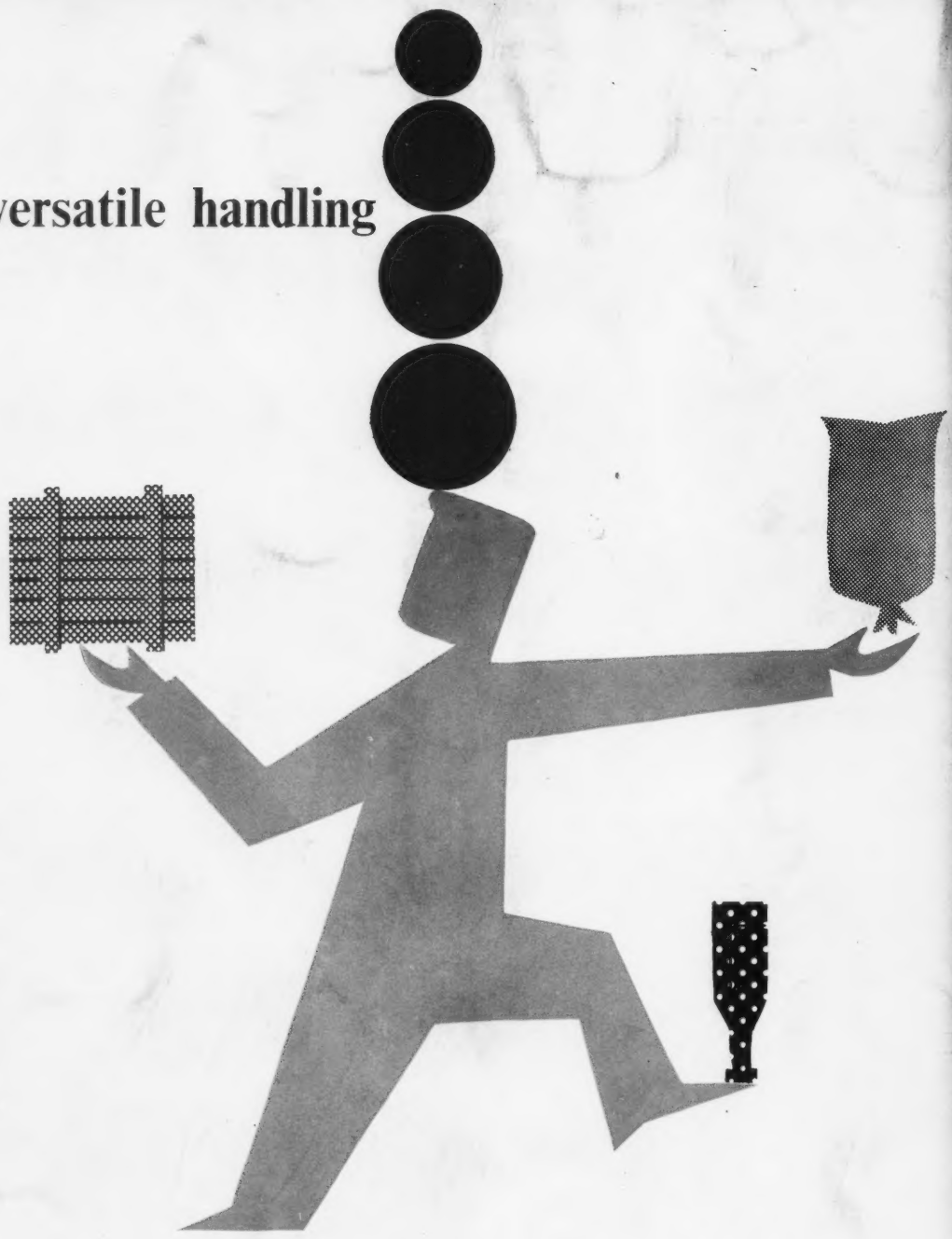

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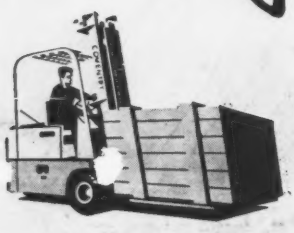

'SKY-ZONE' fork lift trucks

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